Units and dimensions

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Physics, Physical quantities (Fundamental and derived)

- Physics is the branch of science which deals with the study of nature and natural phenomena.
- Applied Physics is the application of the Physics to helping human beings and solving their problem, it is usually considered as a bridge or a connection between Physics & engineering.
- **Physical Quantities**: All quantities in terms of which laws of physics can be expressed and which can be measured are called Physical Quantities.
- Physical quantities can be classified as-

- **Fundamental Quantity:** The quantity which are independent on each other. In mechanics, mass, length and time are called fundamental quantity.
- **Derived Quantity:** Derived quantity is the quantity which is derived from the fundamental quantities e.g. Area is derived quantity.

$$\text{Area} = \text{Length} \times \text{Breadth}$$

$$= \text{Length} \times \text{Length}$$

$$= (\text{Length})^2$$

$$\text{Speed} = \text{Distance} / \text{Time}$$

$$= \text{Length} / \text{Time}$$

Units: fundamental and derived units

- **Unit**: The quantity which is used as standard for measurement is called unit.

Characteristics of Standard Unit: A unit selected for measuring a physical quantity should have the following properties

- It should be well defined i.e. its concept should be clear.
- It should not be change with change in its physical condition like temperature, pressure & stress.
- It should be suitable in size i.e. neither too large nor too small.
- It should not change with place of time.
- It should be reproducible.
- It should be internationally accepted.
- **Classification of Units:** Units can be classified into two categories.
- **Fundamental & Derived**

- The units selected for measurement of three fundamental physical quantities i.e. mass, length and time are called **Fundamental units.**
- **Derived unit The units** which can be derived from the fundamental units are called derived units for example- The units of area, volume, acceleration, force etc. are derived units.

Area = Length x Breadth

= Length x Length

= $(\text{Length})^2$

$=m^2$

Systems of units: CGS, FPS, MKS, SI

System of units is a set of fundamental and derived units. For measurement of physical quantities, the following system are commonly used:-

- **C.G.S system**: In this system, the units of length is centimetre, the unit of mass is gram and the unit of time is second.
- **F.P.S system**: In this system, the unit of length is foot, the unit of mass is a pound and the unit of time is second.
- **M.K.S**: In this system, the unit of length is metre, unit of mass is kg and the unit of time is second.
- **S.I System**: This version is an improved and extended version of M.K.S system of units. It is called international system of unit.
- With the development of science & technology, the three fundamental quantities like mass , length & time were not sufficient as many other quantity like electric current , heat etc. came up. Therefore, more fundamental units in addition to the units of mass, length and time.
- Thus, MKS system was modified with addition of four other fundamental quantities and two supplementary quantities.

Fundamental Quantities and SI Units

Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric Current	ampere	A
Thermodynamic Temperature	kelvin	K
Luminous Intensity	candela	cd
Amount of Substance	mole	mol

Table of Supplementary unit

Sr. No	Name of Physical Quantity	Unit	Symbol
1	Plane angle	Radian	rad
2	Solid angle	Steradian	sr

Advantage of S.I. system:

It is coherent system of unit i.e. the derived units of a physical quantity are easily obtained by multiplication or division of fundamental units.
It is a rational system of units i.e. it uses only one unit for one physical quantity. i.e. It uses as unit Joule (J) for all types of energies (heat, light, mechanical).
It is metric system of units i.e. its multiples & submultiples can be expressed in power of 10.

Definition of SI Unit

- 1 Meter: The distance traveled by light in vacuum during a time of 1/299,792,458 second.
- 1 km = 1000 m, 1 cm = 1/100 m,
- 1 mm = 1/1000 m
- 1 Second is defined in terms of an "atomic clock"– time taken for 9,192,631,770 oscillations of the light emitted by a ^{133}Cs atom.
- 1 Kilogram – the mass of a specific platinum-iridium alloy kept at International Bureau of Weights and Measures near Paris

Dimensions: The dimensions of a derived physical quantity are the powers to which the fundamental units of mass, length and time are written.

Dimensional Formula: A dimensional formula is an expression along with power of mass, length & time which indicates how a derived physical quantity depends upon fundamental physical quantity.

Dimensional Equation: An equation obtained by equating the physical quantity with its dimensional formula is called dimensional equation.

Sr. No.	Physical Quantity	Formula	Dimension	Name of S.I unit	Name of c.g.s unit
1	Force	Mass x acceleration	$[M^1L^1T^{-2}]$	Newton (N)	Dyne
2	Work	Force x distance	$[M^1L^2T^{-2}]$	Joule (j)	Erg
3	Power	Work / time	$[M^1L^2T^{-3}]$	Watt (W)	Erg/s
4	Energy (all form)	Stored work	$[M^1L^2T^{-2}]$	Joule (J)	Erg
5	Pressure,Stress	Force/area	$[M^1L^{-1}T^{-2}]$	Nm^{-2}	Barye
6	Momentum	Mass x velocity	$[M^1L^1T^{-1}]$	$Kgms^{-1}$	
7	Moment of force	Force x distance	$[M^1L^2T^{-2}]$	Nm	
8	Impulse	Force x time	$[M^1L^1T^{-1}]$	Ns	
9	Strain	Change in dimension / original dimension	$[M^0L^0T^0]$	No unit	

10	**Modulus of elasticity**	**Stress / strain**	$[M^1L^{-1}T^{-2}]$	Nm^{-2}	
11	Surface energy	Energy / area	$[M^1L^0T^0]$	Joule/m^2	
12	Surface Tension	Force / length	$[M^1L^0T^{-2}]$	N/m	
13	Co-efficient of viscosity	Force x distance/ area x velocity	$[M^1L^{-1}T^{-1}]$	N/m^2	
14	Moment of inertia	Mass x (radius of gyration)^2	$[M^1L^2T^0]$	Kg-m^2	
15	Angular Velocity	Angle / time	$[M^0L^0T1]$	Rad.per sec	
16	Frequency	1/Time period	$[M^0L^0T^{-1}]$	Hertz	
17	Area	Length x Breadth	$[M^0L^2T^0]$	Metre^2	
18	Volume	Length x breadth x height	$[M^0L^3T^0]$	Metre^3	
19	Density	Mass/ volume	$[M^1L^{-3}T^0]$	Kg/m^3	
20	Speed or velocity	Distance/ time	$[M^0L^1T^{-1}]$	m/s	
21	Acceleration	Velocity/time	$[M^0L^1T^{-2}]$	m/s^2	
22	pressure	Force/area	$[M^1L^{-1}T^{-2}]$	N/m^2	

Principle of Homogeneity of Dimensions: It states that the dimensions of all the terms on both sides of an equation must be the same. According to the principle of homogeneity, the comparison, addition & subtraction of all physical quantities is possible only if they are of the same nature i.e., they have the same dimensions.

Example: A physical relation must be dimensionally homogeneous, i.e., all the terms on both sides of the equation must have the same dimensions.

In the equation, $S = ut + \frac{1}{2} at^2$

dimensions of various quantities in the equation are:

Distance, $S = [L^1]$ Velocity, $u = [L^1T^{-1}]$

Time, $t = [T^1]$ Acceleration, $a = [L^1T^{-2}]$

½ is a constant and has no dimensions.

Thus, the dimensions of the term on L.H.S.

$$S = [L^1]$$

And dimensions of terms on R.H.S are -

$$ut + \frac{1}{2} at^2 = [L^1T^{-1}]\,[T^1] + [L^1T^{-2}]\,[T^2]$$

$$= [L^1] + [L^1]$$

Here, the dimensions of all the terms on both sides of the equation are the same. Therefore, the equation is dimensionally homogeneous.

- **Dimensional Analysis:** A careful examination of the dimensions of various quantities involved in a physical relation is called dimensional analysis. The analysis of the dimensions of a physical quantity is of great help to us in a number of ways as discussed under the uses of dimensional equations:
- **Uses of dimensional equation**: The principle of homogeneity & dimensional analysis has put to the following uses:
- Checking the correctness of physical equation.
- To convert a physical quantity from one system of units into another.
- To derive relation among various physical Quantities.

To check the correctness of Physical relations :

According to principle of Homogeneity of dimensions a physical relation or equation is correct , if the dimensions of all the terms on both sides of the equation are same. If the dimensions of even one term differs from those of others , the equation is not correct.

For Example : Check the correctness of the following formulae by dimensional analysis.

(i)$F=mv^2/r$

Sol. $F = mv^2 / r$

Dimensions of the term on L.H.S

Force, $F = [M^1L^1T^{-2}]$

Dimensions of the term on R.H.S

$$Mv^2/ r = [M^1][L^1T^{-1}]^2 / [L]$$

$$= [M^1L^2T^{-2}] / [L]$$

$$= [M^1L^1T^{-2}]$$

The dimensions of the term on the L.H.S are equal to the dimensions of the term on R.H.S. Therefore, the relation is correct.

Conversion of system of unit (force, work)

To convert from one system of unit to another, a physical quantity is written as

$$Q = nu = n_1 u_1 = n_2 u_2$$

where n_1 is the number in first system, u_1 is the unit of first system, n_2 is the number in second system, u_2 is the unit in second system.

Example 9. Convert a force of 1 newton to dyne.
To convert the force from mks system to cgs system, we need the equation;

$Q = n_1 u_1 = n_2 u_2$,   Here $n_1 = 1$, $u_1 = 1N$, $u_2 = dyne$

Thus $$n_2 = \frac{n_1 u_1}{u_2}$$

$$n_2 = n_1 \frac{M_1 L_1 T_1^{-2}}{M_2 L_2 T_2^{-2}}$$

$$n_2 = n_1 (\frac{M_1}{M_2})(\frac{L_1}{L_2})(\frac{T_1}{T_2})^{-2}$$

$$n_2 = n_1 \left(\frac{kg}{gm}\right)\left(\frac{m}{cm}\right)\left(\frac{s}{s}\right)^{-2}$$

$$n_2 = n_1 \left(\frac{1000gm}{gm}\right)\left(\frac{100cm}{cm}\right)\left(\frac{s}{s}\right)^{-2}$$

$$n_2 = 1(1000)(100)$$

$$n_2 = 10^5$$

Thus 1N = 10^5 Dyne

Example 10. Convert work of 1 erg into joules.

Solution: Here we need to convert work from cgs system to mks system. Thus in the equation

$$n_2 = \frac{n_1 u_1}{u_2}$$

n_1=1, u_1=erg (CGS unit of work) & u_2= joule (SI unit of work)

$$n_2 = n_1 \frac{M_1 L_1^2 T_1^{-2}}{M_2 L_2^2 T_2^{-2}}$$

$$n_2 = n_1 \left(\frac{M_1}{M_2}\right)\left(\frac{L_1}{L_2}\right)^2\left(\frac{T_1}{T_2}\right)^{-2}$$

$$n_2 = n_1 \left(\frac{gm}{kg}\right)\left(\frac{cm}{m}\right)^2\left(\frac{s}{s}\right)^{-2}$$

$$n_2 = n_1 \left(\frac{gm}{1000gm}\right)\left(\frac{cm}{100cm}\right)^2\left(\frac{s}{s}\right)^{-2}$$

$$n_2 = 1(10^{-3})(10^{-2})^2$$

$$n_2 = 10^{-7}$$

Thus 1 erg= 10^{-7} joules

Simple harmonic motion

Learning outcomes

- define SHM and illustrate it with a variety of examples
- describe effects of damping on free vibrations, forced vibrations and resonance
- interpret & use algebraic and graphical representations of SHM
- relate SHM to circular motion
- solve quantitative problems involving SHM

A brief history & contexts

The study of SHM started with Galileo's pendulum experiments (1638, *Two new sciences*).

Huygens, Newton & others developed further analyses.

- pendulum – clocks, seismometers
- ALL vibrations and waves - sea waves, earthquakes, tides, orbits of planets and moons, water level in a toilet on a windy day, acoustics, AC circuits, electromagnetic waves, vibrations molecular and structural e.g. aircraft fuselage, musical instruments, bridges.

Periodic Motion

A motion which repeats itself after a regular Interval of time is called periodic motion. For example pendulum of clock, hands of clock.

Oscillatory Motion

To and fro motion of an object about a fixed mean position is called oscillatory motion. For example pendulum of clock, cantilever etc.

Note: All oscillatory motions are periodic but all periodic motions need not be periodic.

Simple harmonic motion is a special type of periodic motion where the restoring force is directly proportional to the displacement and acts in the direction opposite to that of displacement. Ex- simple pendulum, cantilever, spring-mass system etc.

Vibrations:

The to and fro motion of a body about its mean position in periodic manner is called vibration. Three types of vibrations are:

Free Vibrations

Forced vibrations

Resonant vibrations

Free Vibrations: When a body is set into vibrations and is allowed to vibrate freely under the effect of its own elastic forces, then such vibrations are called free vibrations. For example simple pendulum, spring mass system. The period of vibration in free vibration of simple pendulum is given by

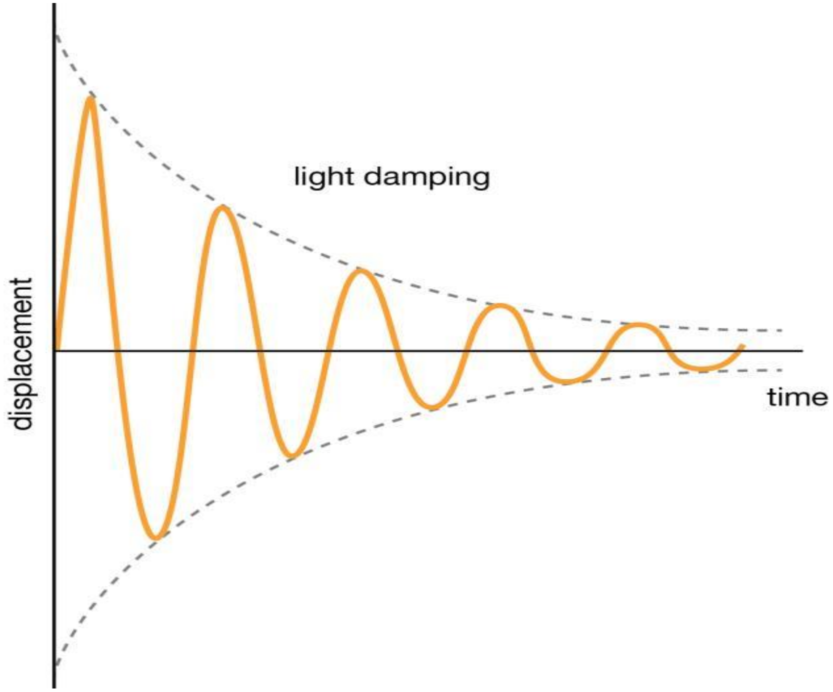
$$T = 2\pi\sqrt{\frac{l}{g}}$$

There are two types of free vibrations.

Damped and undamped.

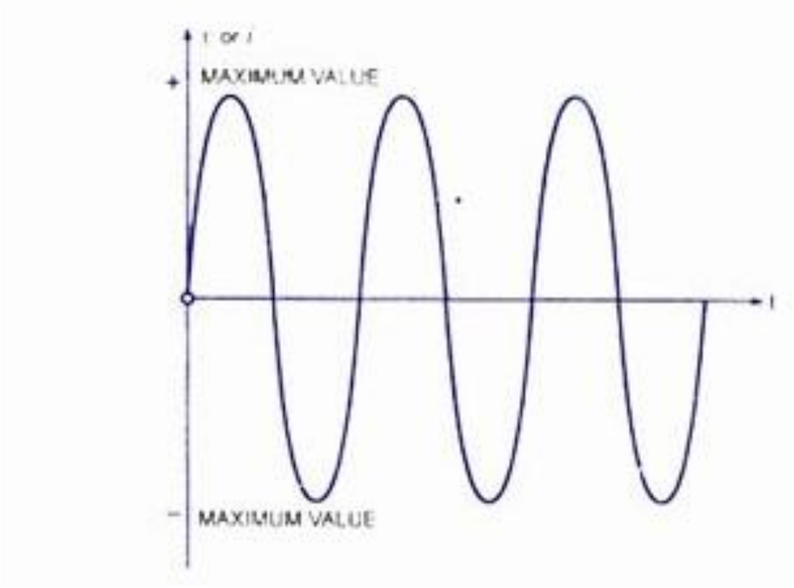
Damped vibrations:

In real world, due to presence of frictional forces, vibrations must do work against these forces. As a system loses energy, the amplitude falls. This is called damping.



Undamped vibrations:

Free vibration in which frictional forces are not present, result into undamped vibrations. This means total energy of the system remains unchanged during the motion and hence the system will vibrate with constant amplitude forever.



Forced Vibrations: If the vibrations are maintained by applying an external periodic force, then such vibrations are called forced vibrations. The frequency of vibration in forced vibration is other than natural frequency of the body. For example, a child's swing vibrates under the effect of external periodic force.

Resonant Vibrations: A special type of forced vibration in which the frequency of applied force matches with natural frequency of the body. If the frequency of external force matches, the amplitude of vibration significantly increases as resonance occurs. It can be helpful for humans as well as it can cause disaster.

Applications of resonance:

(a) Tuning of a radio set: There are many stations sending radio waves of various frequencies causing forced oscillations in the circuit of receiver. When the frequency of tuner(particular setting) equals that of waves from particular broadcasting station, the resonance takes place and hence we can hear only that station, whose amplitude of frequency has increased.

(b) Resonance can cause disaster: Soldiers are ordered to break step while marching across bridge. If the frequency of their footsteps matches with natural frequency of the bridge, resonance will occur and the bridge will oscillate with a destructively large amplitude.

Three particular systems

Mass-on-spring,

$$T = 2\pi\sqrt{\frac{m}{k}}$$

Simple pendulum,

(for small angle oscillations)

$$T = 2\pi\sqrt{\frac{l}{g}}$$

Cantilever is a beam which is fixed at one end and left free to vibrate on another end. The time period of cantilever is given by

$$T = 2\pi\sqrt{\frac{p}{g}}$$

Frequency

The frequency of a wave is the inverse of the PERIOD. That means that the frequency is the #cycles per sec. The commonly used unit is HERTZ(HZ).

$$Period = T = \frac{\text{seconds}}{\text{cycles}} = \frac{3.5s}{1.75cyc} = 2s$$

$$Frequency = f = \frac{\text{cycles}}{\text{seconds}} = \frac{1.75cyc}{3.5\,\text{sec}} = 0.5\, {}^{c}\!/_{s} = 0.5Hz$$

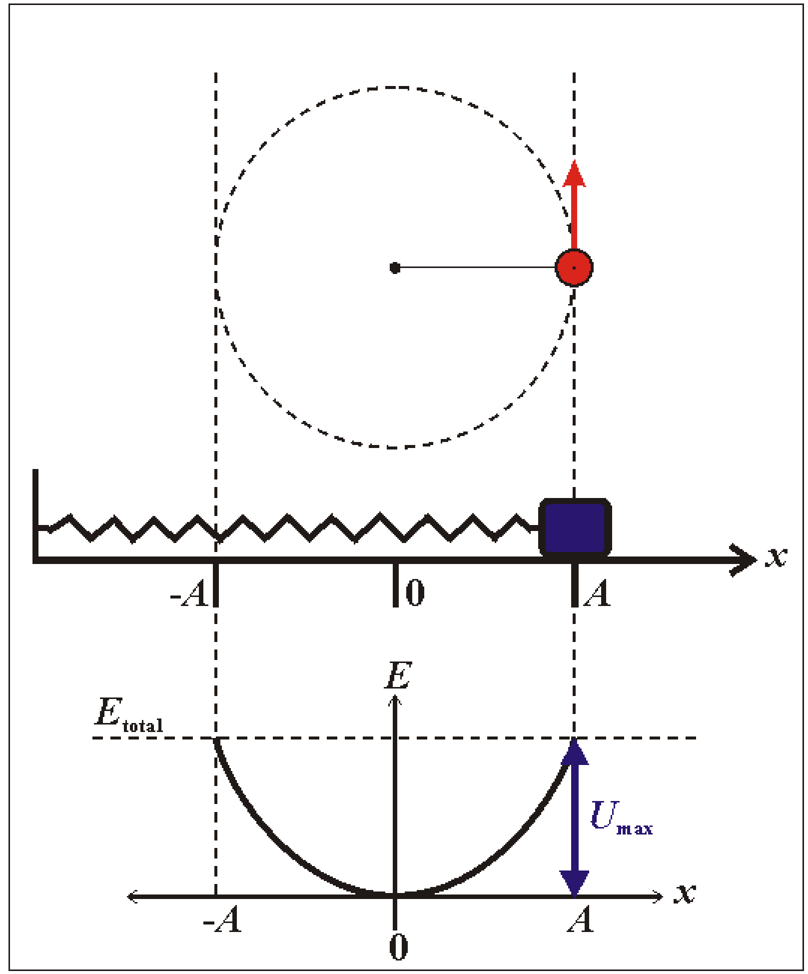
$$T = \frac{1}{f} \quad f = \frac{1}{T}$$

SHM and Uniform Circular Motion

Springs and Waves behave very similar to objects that move in circles.

The radius of the circle is symbolic of the displacement, x, of a spring or the amplitude, A, of a wave.

$$x_{spring} = A_{wave} = r_{circle}$$



The SHM auxiliary circle

An imaginary circular motion gives a mathematical insight into SHM. Its angular velocity is ω

'The connection between SHM and circular motion'

The time period of the motion,

$$T = \frac{2\pi}{\omega}.$$

The frequency of the motion,

$$n = \frac{1}{T} = \frac{\omega}{2\pi}.$$

Displacement of the SHM,

$$y = r\sin(\omega t)$$

SHM equations

Displacement $$y = r\sin(\omega t)$$

At *t* = 0, the object is released from its max displacement.

The velocity, *v,* (rate of change of displacement) is then given by:

$$v = \frac{\mathrm{d}y}{\mathrm{d}t} = \omega r\cos(\omega t)$$

The acceleration, *a*, (rate of change of velocity) is:

$$a = \frac{\mathrm{d}v}{\mathrm{d}t} = -\omega^2 r\sin(\omega t)$$

Note that $$a = -\omega^2 y = -(2\pi n)^2 y$$

Getting a feel for SHM 1

Careful observation of a big pendulum.

There is an equilibrium (rest) position. Displacement, *s*, is the distance from equilibrium.

Discuss, in pairs

1. Where is the mass moving fastest, slowest?
2. Where is the mass's acceleration maximum, zero?
3. Does the time for one complete oscillation depend on the amplitude?
4. What causes the mass to overshoot its equilibrium position?
5. What forces act on the mass? When is the unbalanced force at a maximum value, zero? Do these predictions fit your observations about the acceleration?

Waves and Vibrations

Waves are all around us in everyday life.

Light is a wave.*

*But it can act as a particle…

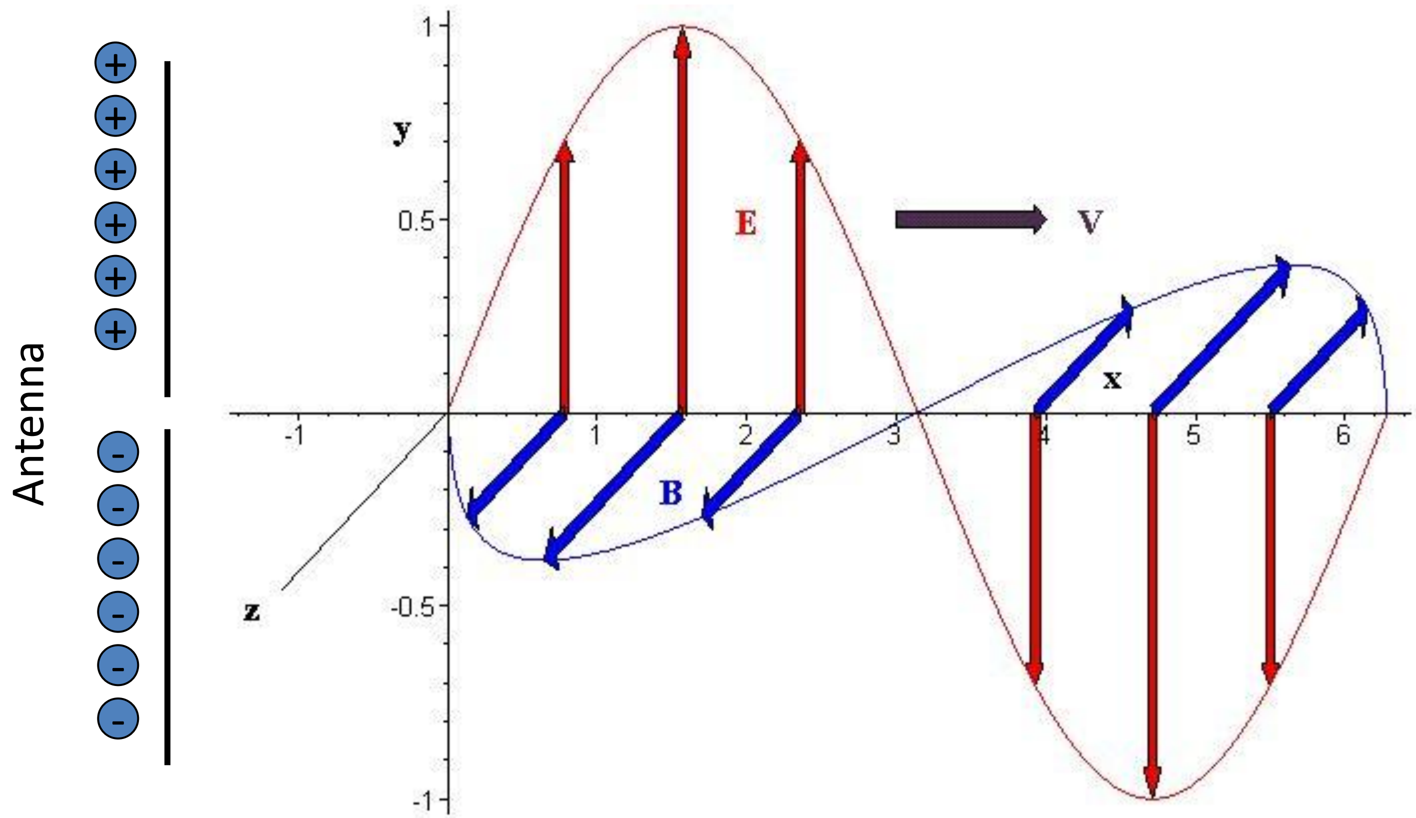
What is a wave?

- A wave is a disturbance that travels through a medium from one location to another.
- A wave is the motion of a disturbance in which energy can be transferred from one location to another. The waves can be of two types:

1. Mechanical wave: The waves which require a material medium for propagation are called mechanical waves. Example sound waves.
2. Electromagnetic wave: The waves which do not require a medium for propagation are called electromagnetic waves. Light waves are electromagnetic in nature.

Light & Radio are Electro-magnetic Waves

Electric Field (and Magnetic Field) move TRANSVERSE to direction of propagation of energy.

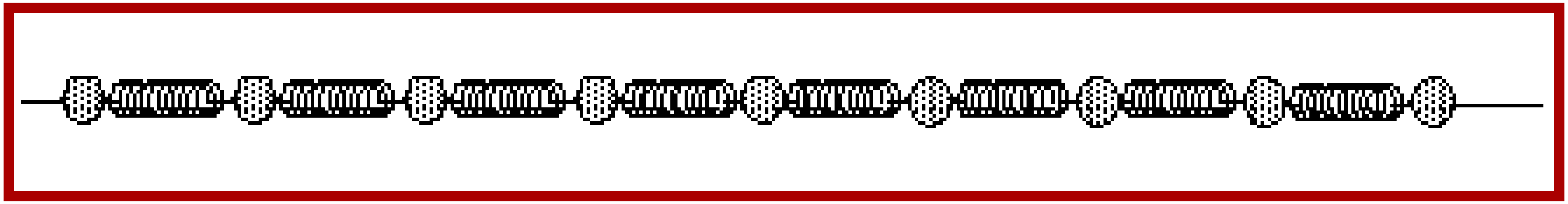


- ***wave*** – a wiggle in space caused by a vibration or disturbance. Wave motion can be of two types

transverse wave: direction of wave and *direction* of medium are perpendicular

longitudinal wave: direction of wave and direction of medium lie along each other (also called compression wave)

Longitudinal Wave



- The wave we see here is a longitudinal wave.
- The medium particles vibrate parallel to the motion of the pulse.
- This is the same type of wave that we use to transfer sound.

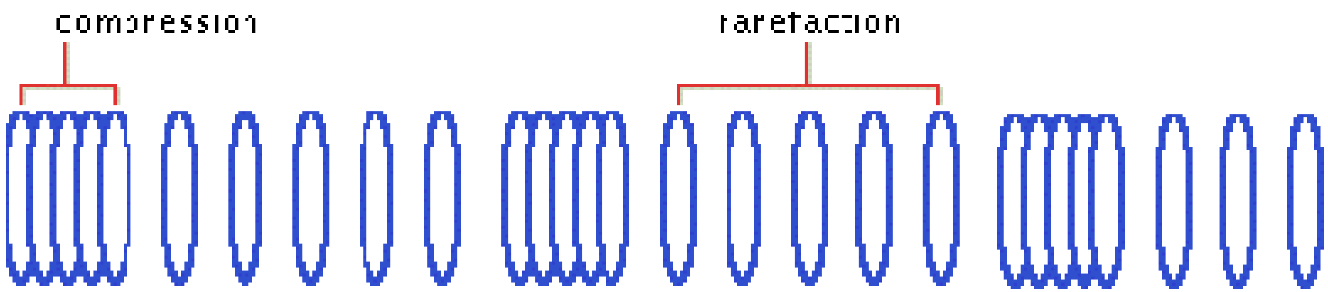


Figure 1: Longitudinal Wave

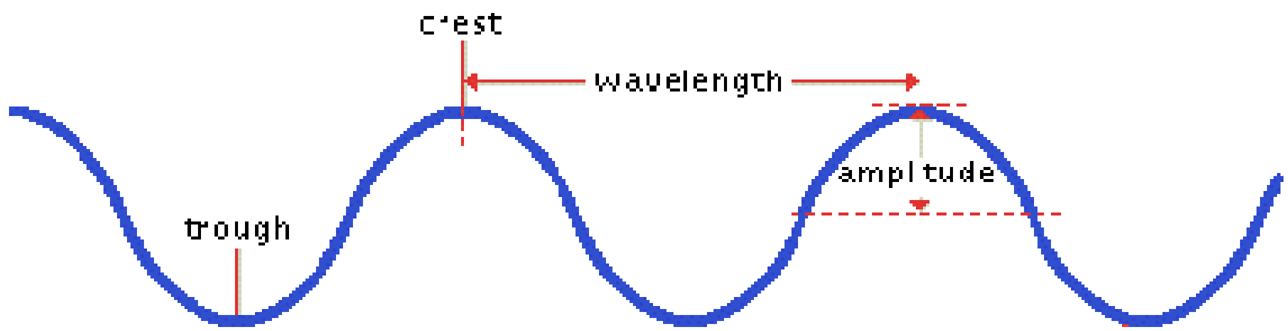
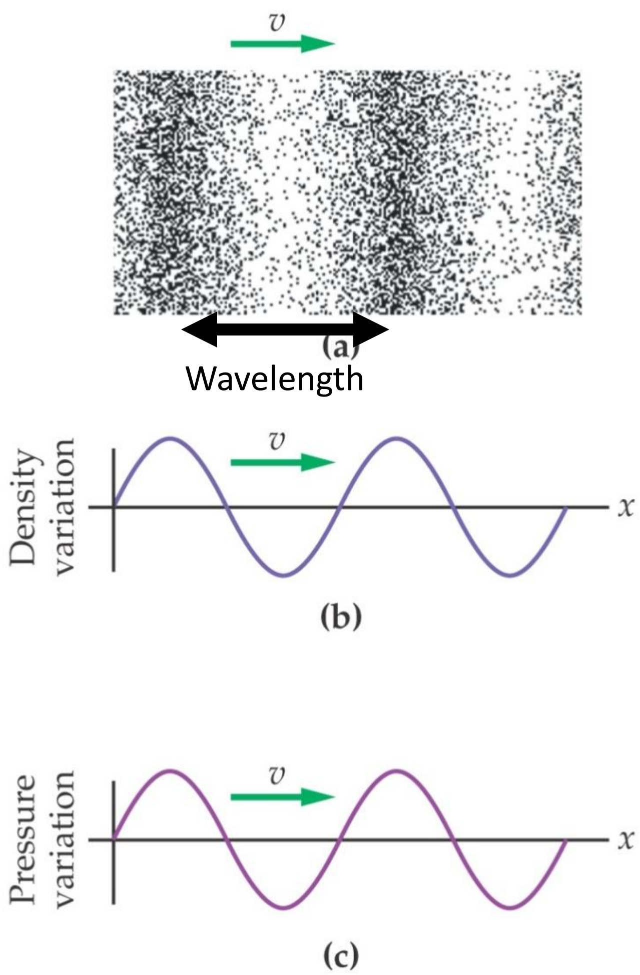


Figure 2: Transverse Wave

Motion of Longitudinal Wave



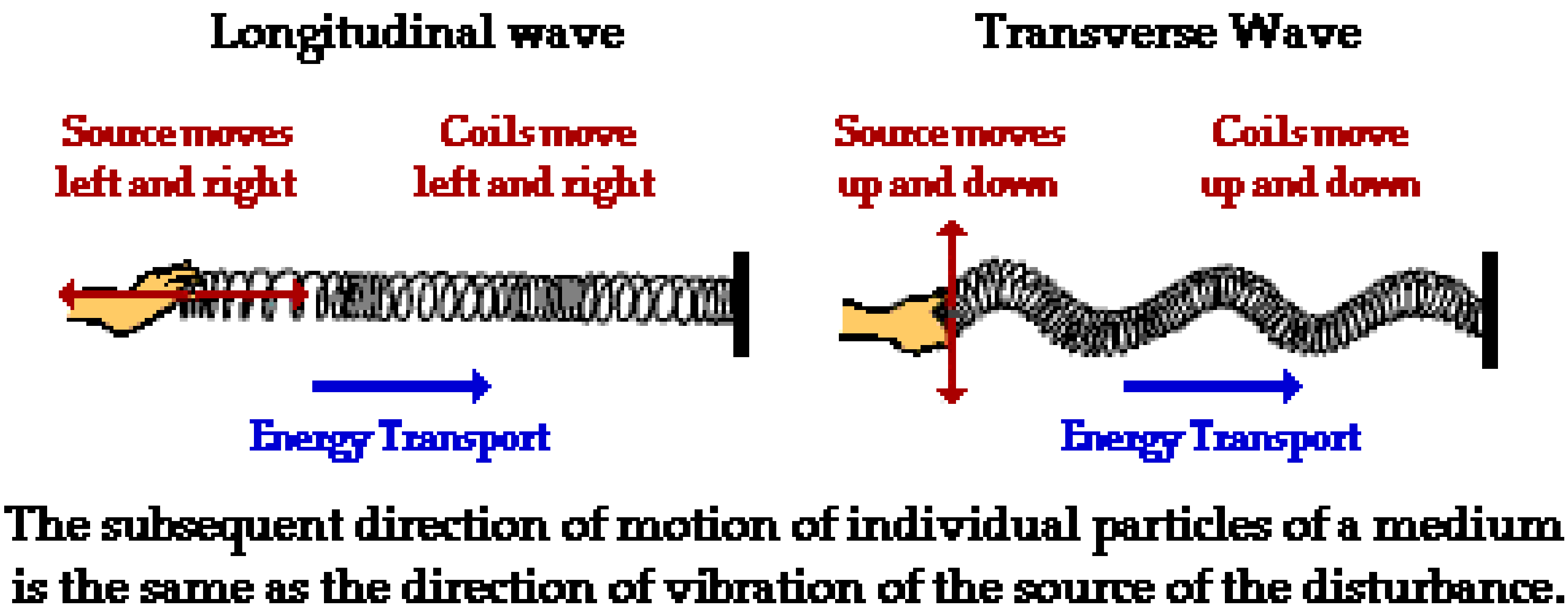
- Pressure wave
- Oscillation of local pressure and gas density

Transverse waves

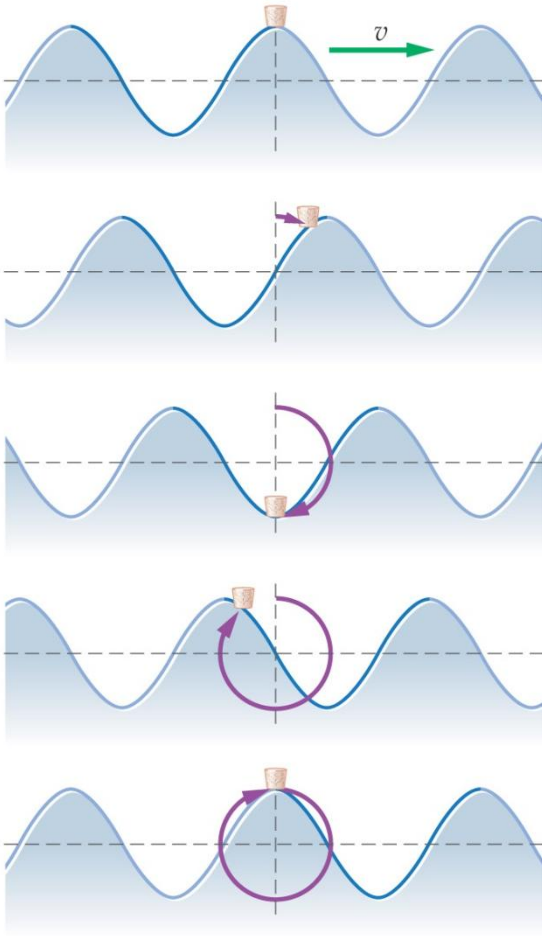
- A second type of wave is a transverse wave.
- We said in a longitudinal wave the pulse travels in a direction parallel to the disturbance.
- In a transverse wave the pulse travels perpendicular to the disturbance.

Transverse Waves

- The differences between the two can be seen



Water waves combine motions



Complex motion: combination of transverse and longitudinal motion.

Key characteristic of these waves

- Energy (in the form of motion) can be transmitted by the wave
- The medium (the string, the air, the water) does not move at the speed of the wave—it essentially "stays put"
- The energy of the wave is transmitted through the medium from one piece of matter to another
- Note that light waves travel without the need for a medium at all!

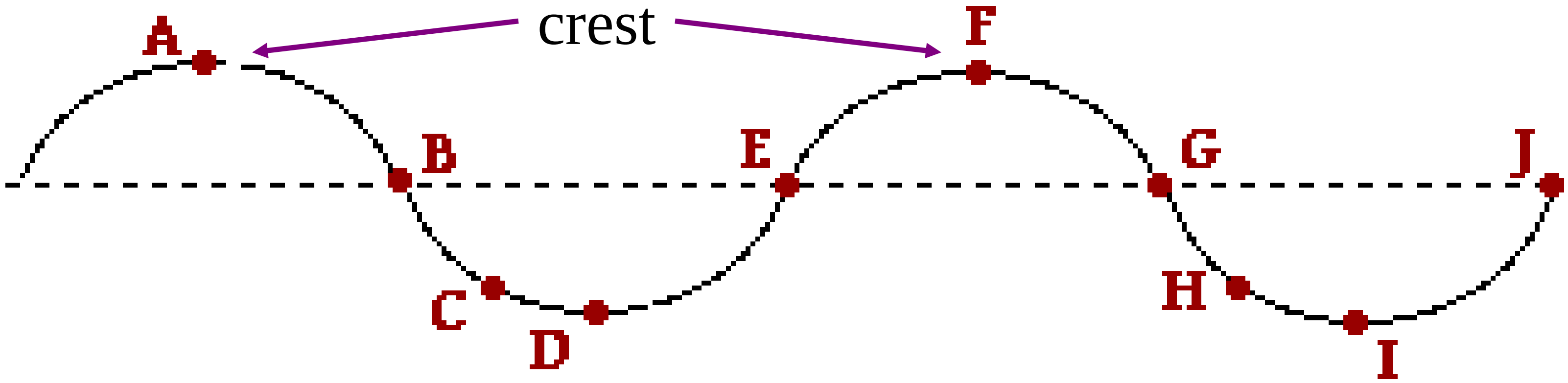
LONGITUDINAL	TRANSVERSE
1. The particles of medium vibrate in the same direction.	1. The particles move at right angles to the direction of wave propagation.
2. They are possible in all kinds of media.	2. They are possible only in solids.
3. They consist of regions of compression and rarefaction.	3. They consist of crests and troughs.
4. They cannot be polarised.	4. They can be polarised.
5. Sound waves in air is an example of longitudinal waves.	5. Vibrations in a string is an example of transverse waves.

Sound wave	Light wave
(a) Velocity of sound waves in air is approximately 330 m s^{-1}.	(a) Velocity of light in air is approximately 3×10^8 m s^{-1}.
(b) Sound requires medium for propagation and hence can not travel through vacuum.	(b) Light wave can travel through vacuum.
(c) Sound wave is longitudinal.	(c) Light waves are transverse wave.
(d) Sound waves are mechanical waves.	(d) Light wave is a type of electromagnetic wave.
(e) Velocity of sound wave increases with the increase in density of the medium.	(e) Speed of light in more dense medium is slower than in the less dense medium.
(f) Exhibit reflection, refraction diffraction and interference properties.	(f) Exhibit reflection, refraction, diffraction and interference properties.

Waves are everywhere in nature

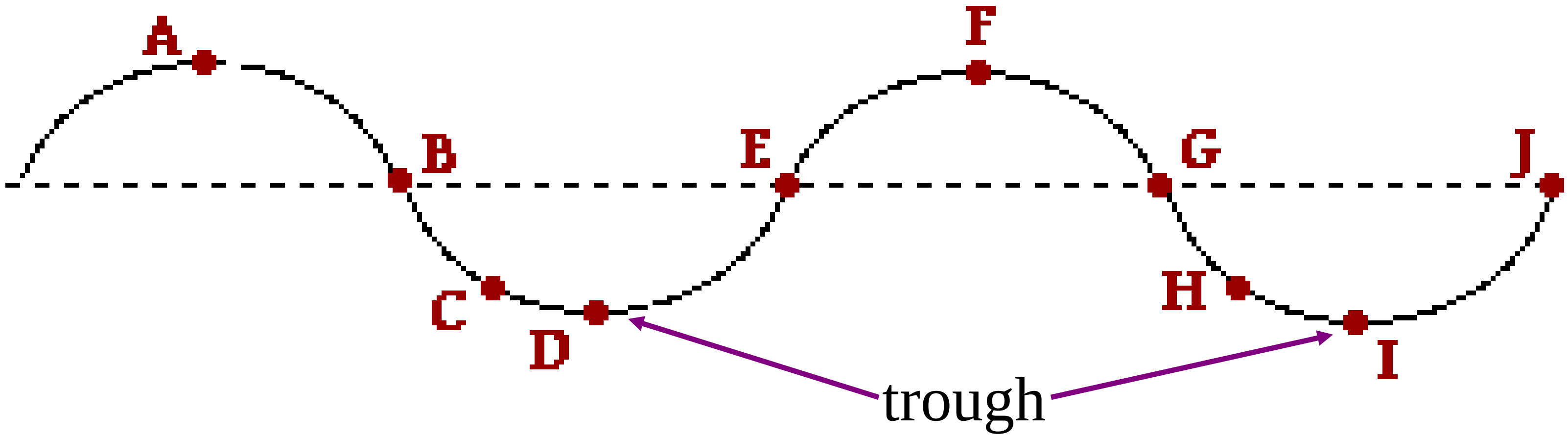
- Sound waves,
- visible light waves,
- radio waves,
- microwaves,
- water waves,
- sine waves,
- telephone chord waves,
- stadium waves,
- earthquake waves,
- waves on a string,
- slinky waves (spring)

Anatomy of a Wave



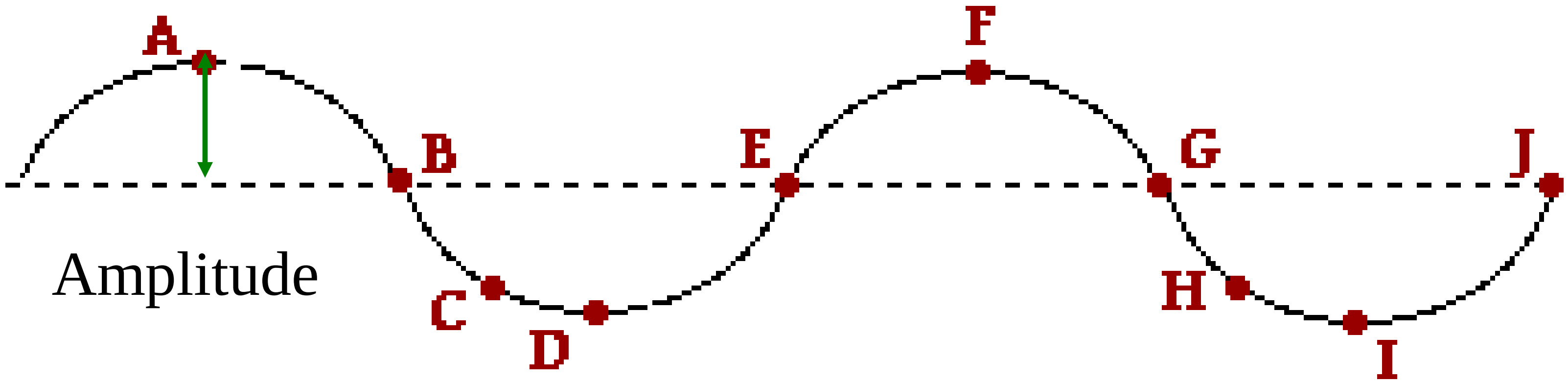
- The points A and F are called the **CRESTS** of the wave.
- This is the point where the wave exhibits the maximum amount of positive or upwards displacement

Anatomy of a Wave



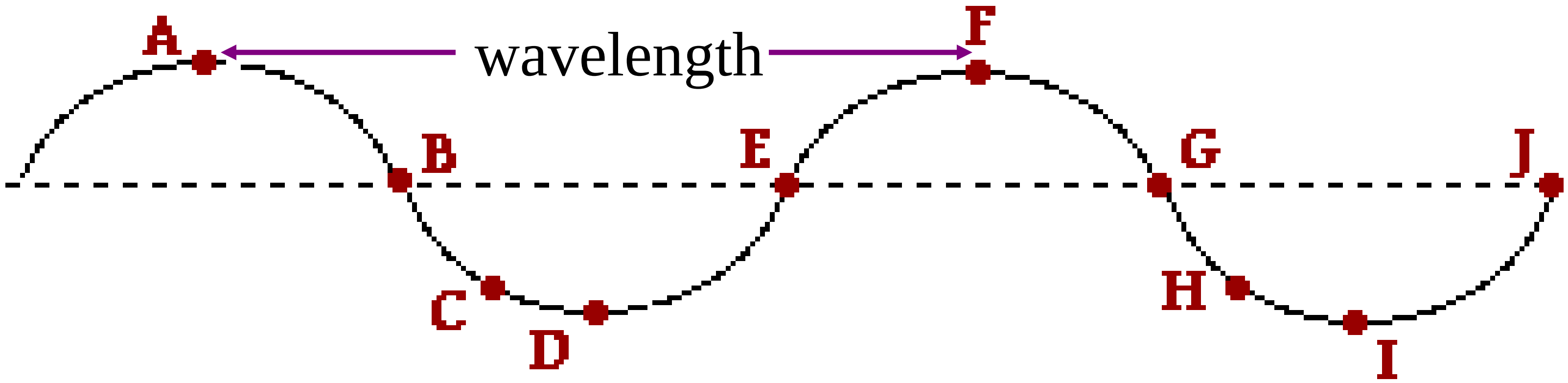
- The points D and I are called the **TROUGHS** of the wave.
- These are the points where the wave exhibits its maximum negative or downward displacement.

Anatomy of a Wave



- The distance between the dashed line and point A is called the **Amplitude** of the wave.
- This is the maximum displacement that the wave moves away from its equilibrium.

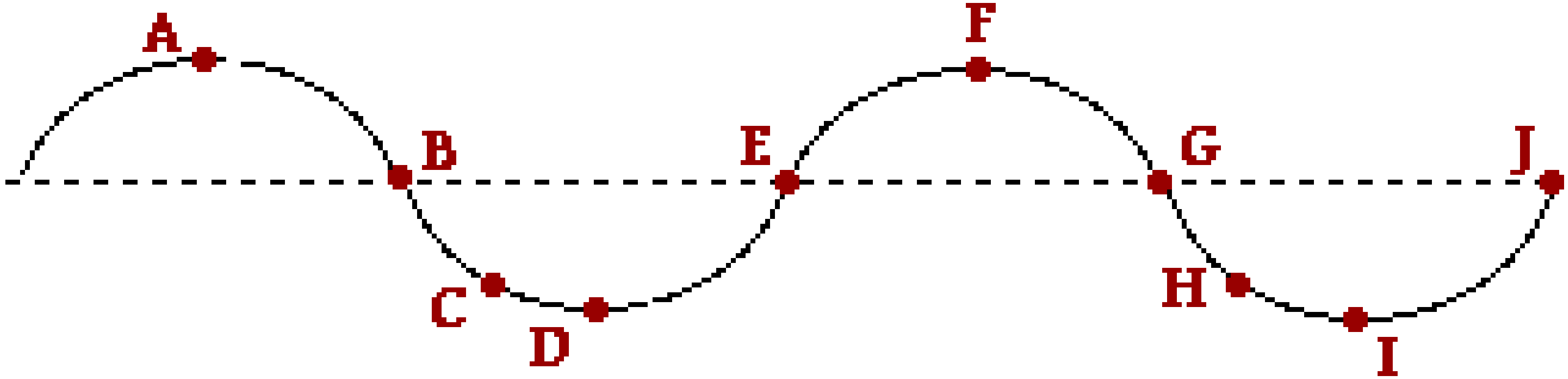
Anatomy of a Wave



- The distance between two consecutive similar points (in this case two crests) is called the **wavelength.**
- This is the length of the wave pulse.
- Between what other points is can a wavelength be measured?

Anatomy of a Wave

- What else can we determine?
- We know that things that repeat have a frequency and a period. How could we find a frequency and a period of a wave?



Wave Speed

- We can use what we know to determine how fast a wave is moving.
- What is the formula for velocity?
  – velocity = distance / time
- What distance do we know about a wave
  – wavelength
- and what time do we know
  – period

Wave Speed

- So if we plug these in we get
  - velocity = length of pulse / time for pulse to move pass a fixed point
  - $v = \lambda / T$
  - we will use the symbol λ to represent wavelength
- $v = \lambda / T$
- but what does T equal
  - $T = 1 / f$
- so we can also write
  - $v = f \lambda$
  - velocity = frequency * wavelength

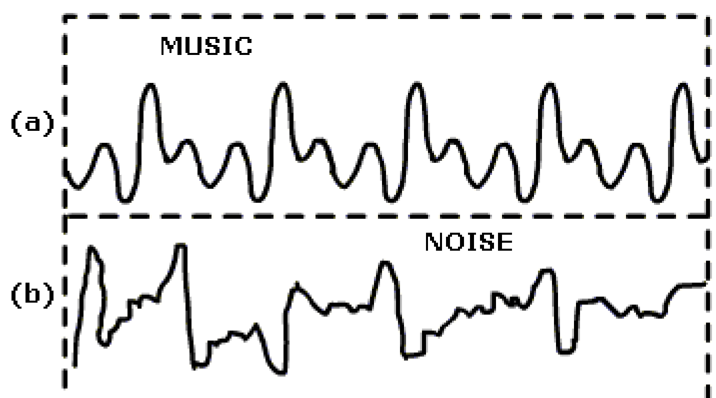
Acoustics: Acoustics is the branch of physics which deals with the generation, Propagation and properties of sound waves .

Acoustics of buildings: It is a branch of acoustics which deals with the study of public halls, theatres etc to have best sound effects.

Sound is a longitudinal wave, which means that the vibration of the air is in the direction of travel of the sound wave.

Noise is unwanted or unpleasant sound having loud and irregular amplitude.

Musical sound produces pleasant effect on the listener. It has regular amplitude.



Reverberation is the persistence or prolongation of original sound after the source has stopped emitting sound.

Reverberation time is the time for which sound persists in a hall after the source has stopped emitting sound.

Echo is the repetition of original sound after reflection from an obstacle. The echo is different from reverberation as an echo is a distinct sound heard after at least 0.1s of original sound.

Absorption Coefficient

The absorption coefficient of a material indicates the proportion of sound which is absorbed by the surface compared to the total sound energy incident. A large, fully open window would offer no reflection as any sound reaching it would pass straight out and no sound would be reflected. This would have an absorption coefficient of 1. Thus it is measured in units of OWU (open window unit).

Standard reverberation time : It is defined as the time taken by sound intensity to fall to its one millionth part after the source has stopped emitting sound. Prof. W.C. Sabine has given the formula to determine the standard reverberation time of a hall. It is known as sabine's formula.

$$T = \frac{0.16V}{\sum as}$$

Where V is volume of the hall, s is area of absorbing surface and a is absorption coefficient.

Methods to control reverberation time:

1) Providing a few open windows: As open windows are perfect absorbers of incident sound, hence by adjusting the number of windows, desired reverberation time can be obtained.
2) Covering the walls and floor by absorbing material: Sound absorbing material like fibre board, asbestos sheet are used to cover the walls. The floor is carpeted. All these help in decreasing the reverberation time.

3) Using heavy curtains with folds: The curtains also help in absorption of sound and they help in controlling the reverberation time.
4) Having a good number of audience: The presence of audience also increases the absorption of sound.
5) Using upholstered seats in the hall: The seats provide the same absorption of sound whether an audience is sitting in the hall or not.
6) Using false ceiling: The false ceiling is a suitable absorbing material that helps in controlling the reverberation time.

Introduction to Ultrasonics

Properties of Ultrasonic waves

Applications of Ultrasonics

- The word **ultrasonic** combines the Latin roots ultra, meaning **‘beyond’** and sonic, or **sound**.
- The sound waves having frequencies above the audible range i.e. above 20000Hz are called **ultrasonic waves**.
- Generally these waves are called as **high frequency waves**.
- The field of ultrasonics have applications for imaging, detection and navigation.
- The broad sectors of society that regularly apply ultrasonic technology are the medical community, industry, the military and private citizens.

Properties of ultrasonic waves

(1) They have a high energy content.

(2) Just like ordinary sound waves, ultrasonic waves get reflected, refracted and absorbed.

(3) They can be transmitted over large distances with no appreciable loss of energy.

(4) They produce intense heating effect when passed through a substance.

Ultrasonics Production

Ultrasonic waves are produced by the following methods.

(1) Magneto-striction generator or oscillator

(2) Piezo-electric generator or oscillator

Applications of Ultrasonic Waves in Engineering

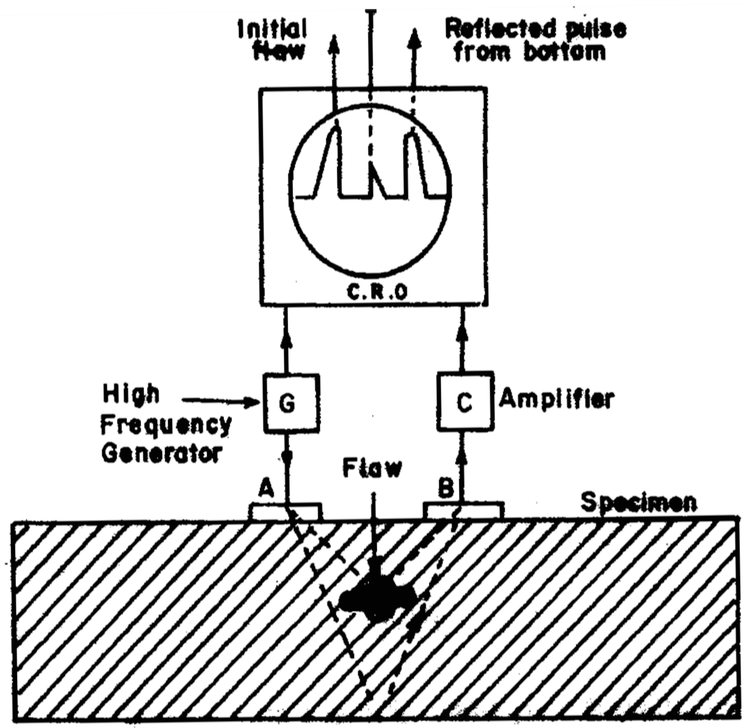
(1)Detection of flaws in metals (Non Destructive Testing –NDT*)*

Principle

- Ultrasonic waves are used to detect the presence of flaws or defects in the form of cracks, blowholes porosity etc., in the internal structure of a material
- By sending out ultrasonic beam and by measuring the time interval of the reflected beam, flaws in the metal block can be determined.

Experimental setup

It consists of an ultrasonic frequency generator and a cathode ray oscilloscope (CRO),transmitting transducer(A), receiving transducer(B) and an amplifier.



Working

- In flaws, there is a change of medium and this produces reflection of ultrasonic at the cavities or cracks.
- The reflected beam (echoes) is recorded by using cathode ray oscilloscope.
- The time interval between initial and flaw echoes depends on the range of flaw.
- By examining echoes on CRO, flaws can be detected and their sizes can be estimated.

Features

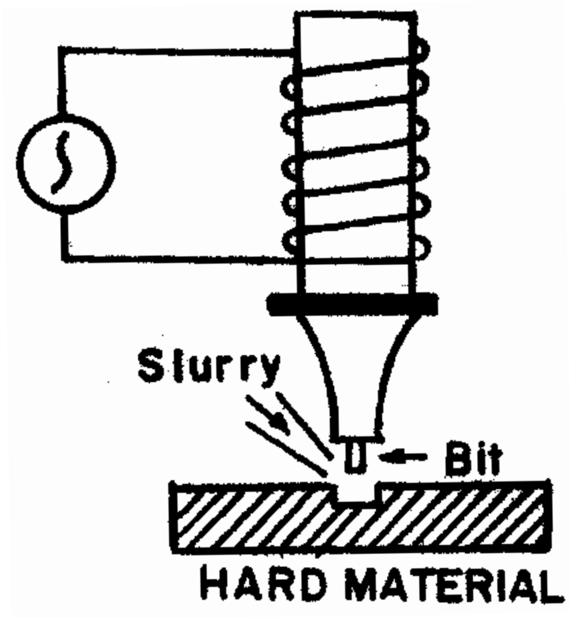
- This method is used to detect flaws in all common structural metals and other materials like rubber tyres etc.

- The method is very cheap and of high speed of operation.

- It is more accurate than radiography.

(2) Ultrasonic Drilling

- Ultrasonics are used for making holes in very hard materials like glass, diamond etc.
- For this purpose, a suitable drilling tool bit is fixed at the end of a powerful ultrasonic generator.
- Some slurry (a thin paste of carborundum powder and water) is made to flow between the bit and the plate in which the hole is to be made
- Ultrasonic generator causes the tool bit to move up and down very quickly and the slurry particles below the bit just remove some material from the plate.
- This process continues and a hole is drilled in the plate.

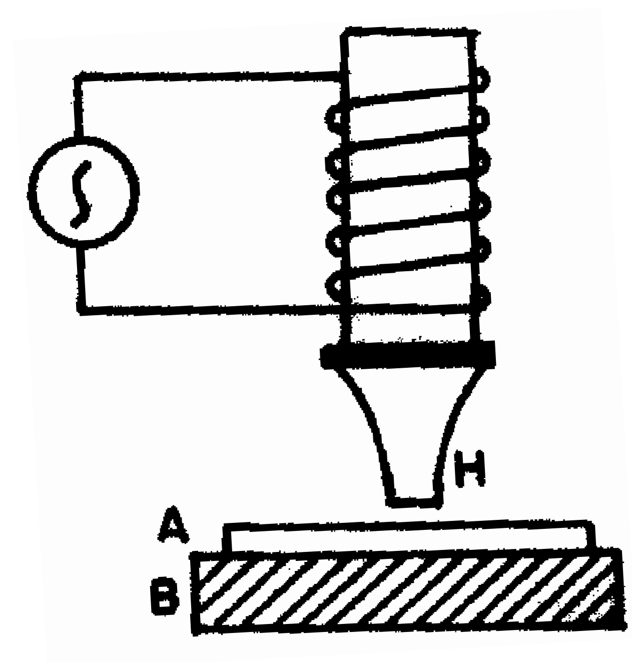


(3) Ultrasonic welding

- The properties of some metals change on heating and therefore, such metals cannot be welded by electric or gas welding.

- In such cases,the metallic sheets are welded together at room temperature by using ultrasonic waves.

- For this purpose, a hammer H is attached to a powerful ultrasonic generator as shown in Figure



- The metallic sheets to be welded are put together under the tip of hammer H.

- The hammer is made to vibrate ultrasonically. As a result, it presses the two metal sheets very rapidly and the molecules of one metal diffuse into the molecules of the other.

- Thus, the two sheets get welded without heating. This process is known as ***cold welding***.

(4) Ultrasonic soldering

- Metals like aluminium cannot be directly soldered.However, it is possible to solder such metals by ultrasonic waves.
- An ultrasonic soldering iron consists of an ultrasonic generator having a tip fixed at its end which can be heated by an electrical heating element.
- The tip of the soldering iron melts solder on the aluminium and the ultrasonic vibrator removes the aluminium oxide layer.
- The solder thus gets fastened to clear metal without any difficulty.

(5) Ultrasonic cutting and machining

Ultrasonic waves are used for cutting and machining.

(6) Ultrasonic cleaning

It is the most cheap technique employed for cleaning various parts of the machine, electronic assembles, armatures, watches etc., which cannot be easily cleaned by other methods.

(7) SONAR

- SONAR is a technique which stands for ***Sound Navigation and Ranging***.
- It uses ultrasonics for the detection and identification of under water objects.
- The method consists of sending a powerful beam of ultrasonics in the suspected direction in water.
- By noting the time interval between the emission and receipt of beam after reflection, the distance of the object can be easily calculated.
- The change in frequency of the echo signal due to the Dopper effect helps to determine the velocity of the body and its direction.

- Measuring the time interval (t) between the transmitted pulses and the received pulse, the distance $d = \frac{vt}{2}$ between the transmitter and the remote object is determined using the formula., where v is the velocity of sound in sea water.
- The same principle is used to find the depth of the sea.

Applications of ultrasonics

1. Sonar is used in the location of shipwrecks and submarines on the bottom of the sea.
2. It is used for fish-finding application .
3. It is used for seismic survey.

Some Other Applications of Ultrasonics

(1) Ultrasonic guidance for the blind

- Ultrasonic waves are used for guiding the blind who carries a walking stick containing an ultrasonic transmitter and receiver.

- Ultrasonic signals reflected from any obstacles are fed to the head phones through a suitable electronic circuit which enables the blind person to detect and estimate the distance of the obstacle.

(2)Ultrasound in research

- Scientists often use in research, for instant to break up high molecular weight polymers, thus creating new plastic materials.
- Indeed, ultrasound also makes it possible to determine the molecular weight of liquid polymers, and to conduct other forms of investigation on the physical properties of materials.
- Ultrasonic can also speed up certain chemical reactions. Hence it has gained application in agriculture, that seeds subjected to ultrasound may germinate more rapidly and produce higher yields.

OPTICS AND OPTICAL FIBRES

TIR and optical fibres

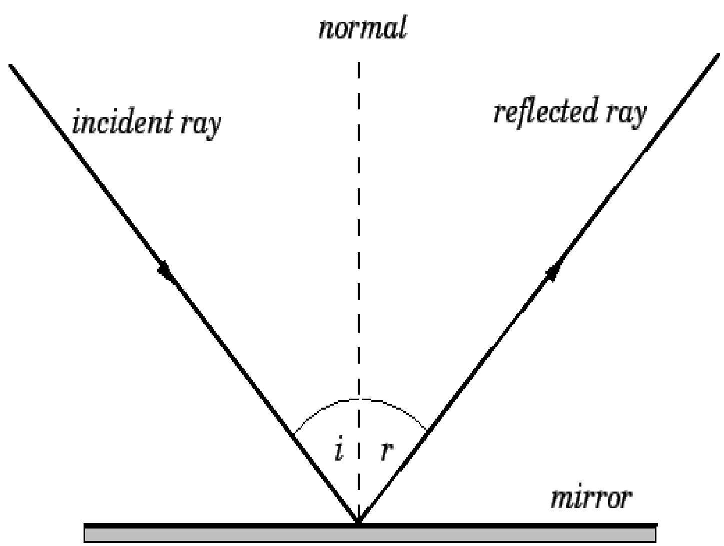
Aims:

- To recall the meaning of critical angle c
- To recall and use the relationship between critical angle and refractive index: sin c = 1/n
- To describe the role of total internal reflection in transmitting information along optical fibres and in prisms.
- To understand the difference between analogue and digital signals.

Reflection of light: When a ray of light incident on any surface and comes back to same medium, then it is called reflection. The plane mirror is a good example to understand reflection .

Laws of reflection:

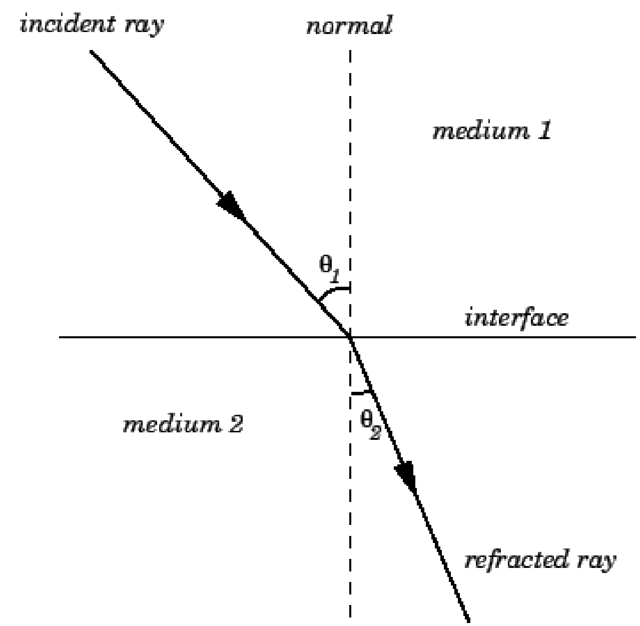
1) The incident ray, the reflected ray and the normal at the point of incidenc, all lie in the same plane.
2) The angle of incidence is equal to angle of reflection.



Refraction of light: When a light ray passes from one transparent medium to another, it gets deviated from its original path while crossing the interface of two media. The phenomena of bending of light rays from their original path while passing from one medium to another is called refraction.

Laws of refraction:

1) The incident ray, the refracted ray and the normal all lie in the same plane.
2) The ratio of sine of angle of incidence to the sine of angle of refraction is a constant for a given pair of media.



$$\mu = \frac{\sin i}{\sin r}$$

Refractive index :

The refractive index of a medium is defined is the ratio of velocity of light in air to the velocity of light in that medium.

$$\mu = \frac{\text{velocity of light in air}}{\text{velocity of light in that medium}}$$

For example the refractive index of glass is 1.5. The index increases with increase in optical density. For example- diamond has high refractive index of 2.6.

Lens formula:

The focal length f of a lens is related to object distance u and image distance v as

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

Power of a lens:

Power of a lens is defined as the reciprocal of the focal length measured in metre. The unit of power is dioptre indicated by symbol 'D'.

$$P = \frac{1}{f\,(metre)}$$

Microscope : A microscope is an optical instrument which enables us to see small objects in a better way. There are two types of microscope:

1. Simple microscope.
2. Compound microscope.

Uses:

1. Biological scientists use microscope to see microorganisms and their behavior.
2. Forensic science experts use microscope to analyze the evidences.
3. Jewelers use it to see the details of pieces they are working with.
4. Environmentalist use it to test the soil and water samples for presence of pollutants.
5. Geologist use it to test the composition of different types of rocks.
6. They are used in various experiments in schools and colleges.

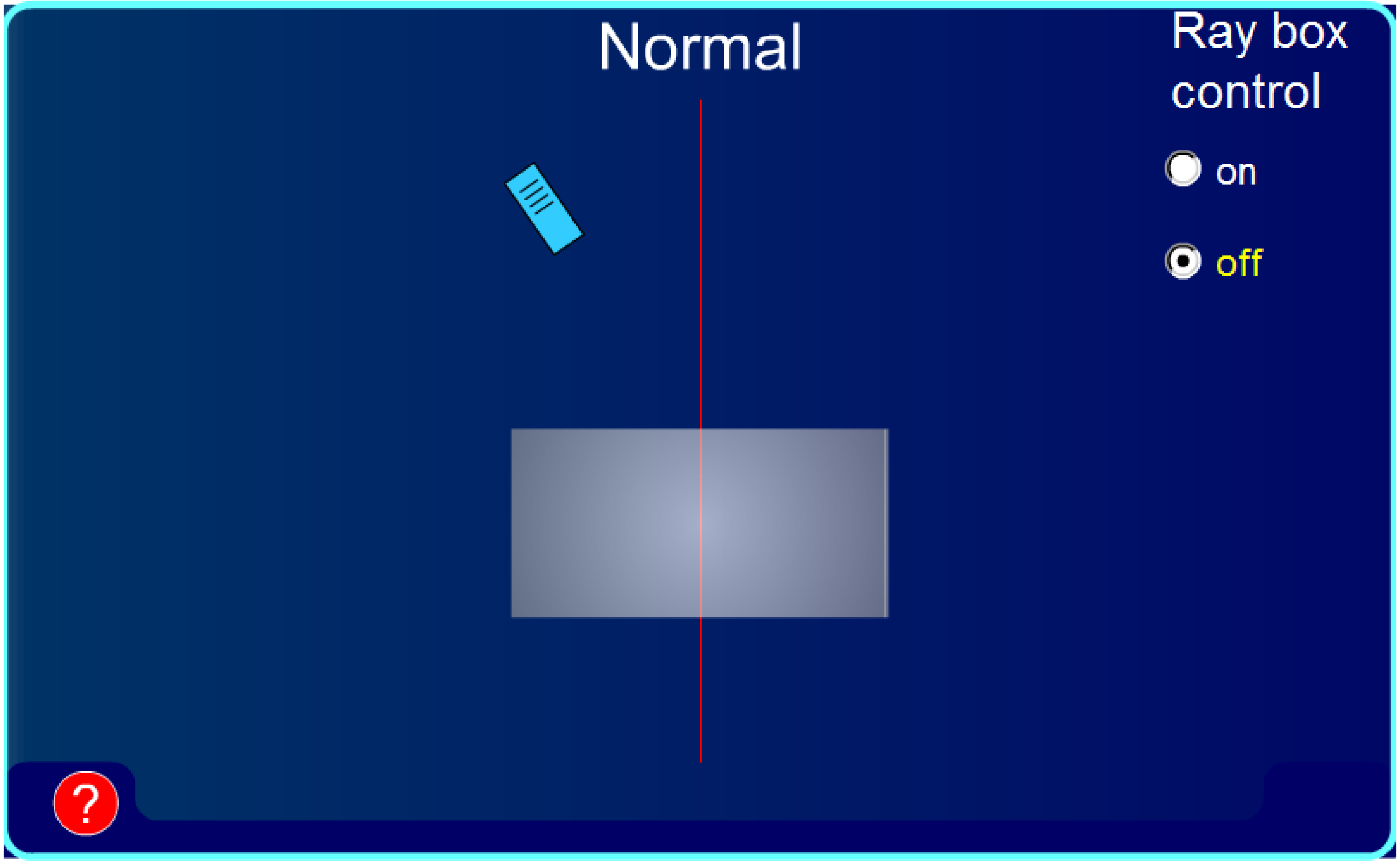
Telescope is an optical instrument which is used to see distant objects clearly. There are three types of telescopes:

1. Astronomical (to see astronomical objects)
2. Terrestrial (To see objects on earth)
3. Galilean (modification of terrestrial telescope)

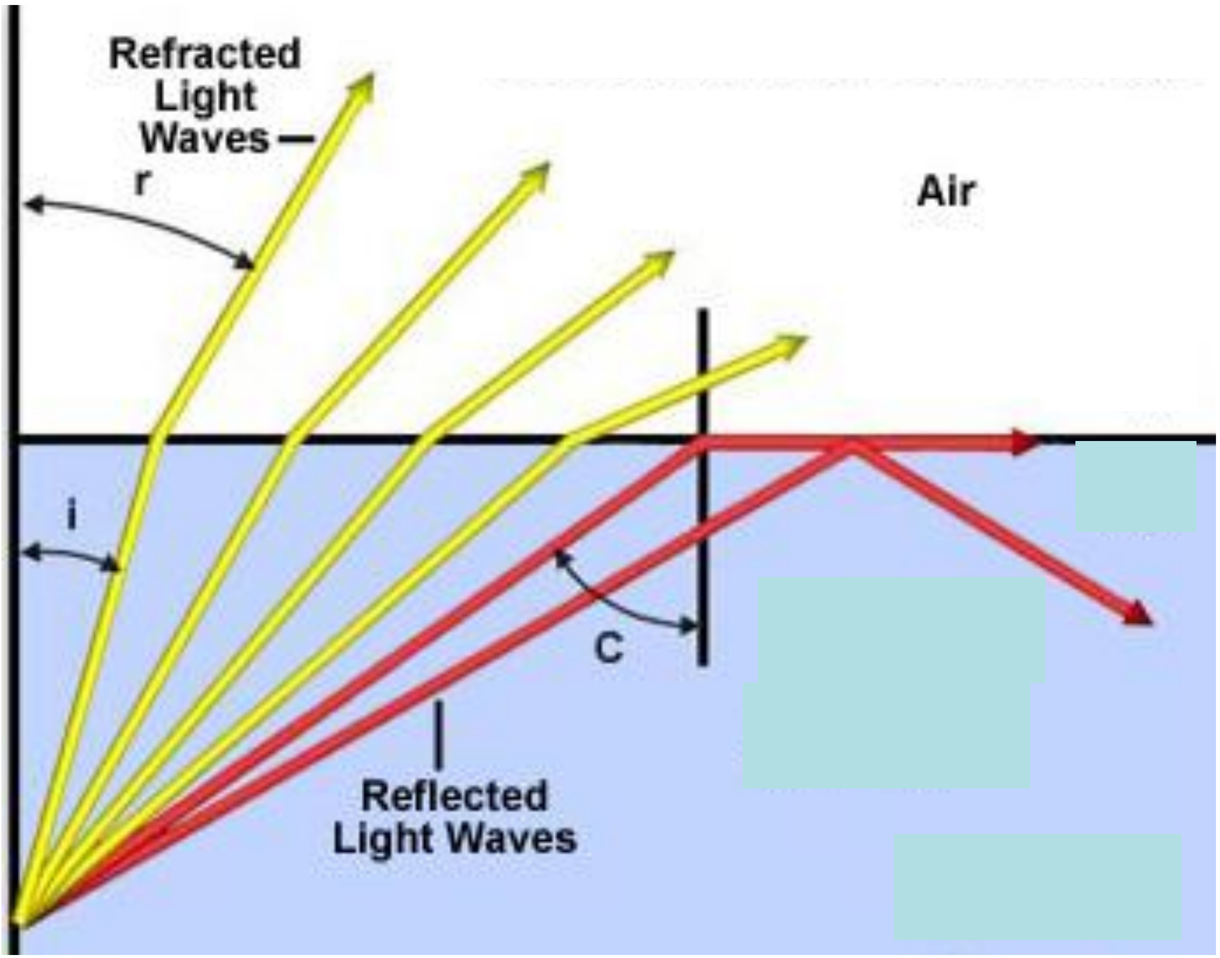
Uses of telescope:

1. Astronomical objects are seen by using telescope by astronomers.
2. Telescope are used in laboratories to perform different experiments and finding values of different quantities.\
3. Spectrometry uses telescope to find wavelength of light and bandwidth etc.
4. It is used in spy glasses and long focus camera lenses.

When light passing out of the glass block its angle increases



No more than ninety degrees

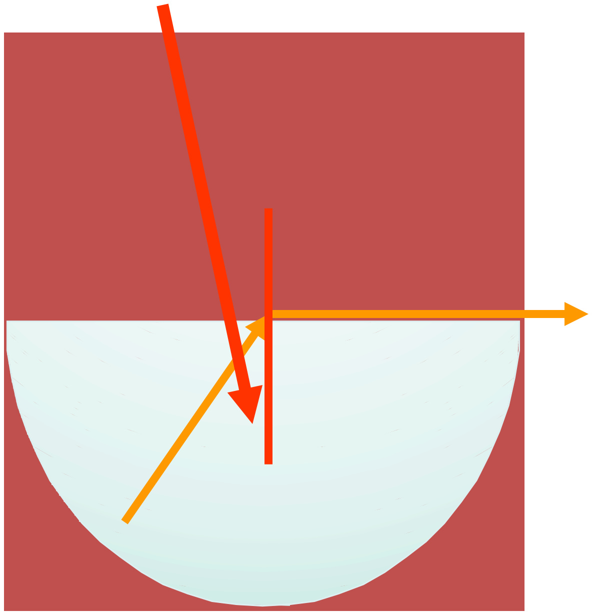


As soon as the angle of refraction reaches 90, the light can no longer be refracted.

What happens to the light? Well the light is reflected back inside the material.

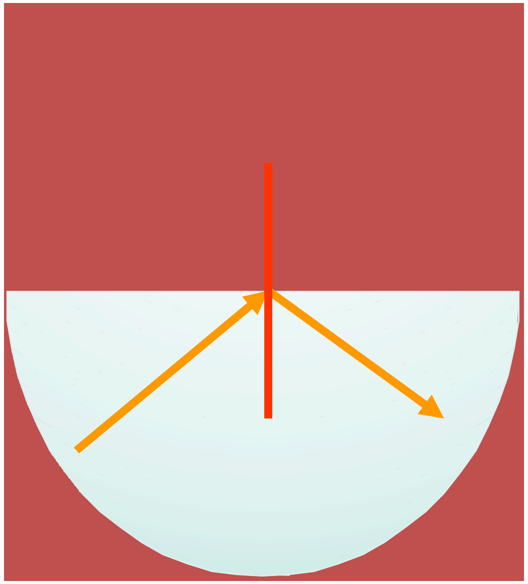
This angle is called the **critical angle** (∠ c).

The angle at which total internal reflection first occurs is called the critical angle.



∠ i = ∠ c

Critical case



∠ i > ∠ c

Total internal reflection (TIR)

Different materials have different critical angles. Diamond has the lowest at 24° , which is why it reflects so much light.

Critical calculations

The critical angle for a material depends upon the refractive index. The higher the refractive index, the lower the critical angle. It can be calculated using the following formula:

$$\sin c = 1/n$$

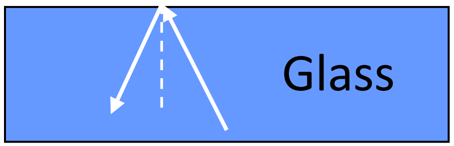
Where:

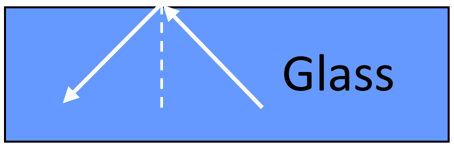
n = Refractive index,

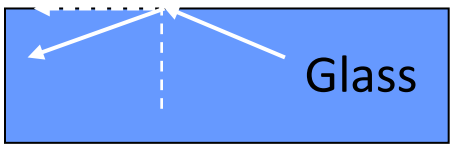
c = Critical angle at which TIR first occurs.

Total Internal Reflection

- Recall that rays moving from glass (slow) to air (fast) bend away from the normal
- The amount by which they bend away depends on the material
- For any material, we can find an angle where there is no transmitted ray, called the critical angle







Critical angle – Example 1

Calculate the critical angle for a glass block of refractive index 1.45

$$\sin(c) = 1 / n$$

$$\sin(c) = 1 / 1.45$$

$$\sin(c) = 0.69$$

$$c = 44^{\circ}$$

Critical angle – Example 2

Calculate the refractive index of a material where TIR occurs at a critical angle of 37º

$$\sin(c) = 1 / n$$

$$n = 1 / \sin(c)$$

$$n = 1 / \sin(37)$$

$$n = 1 / 0.60$$

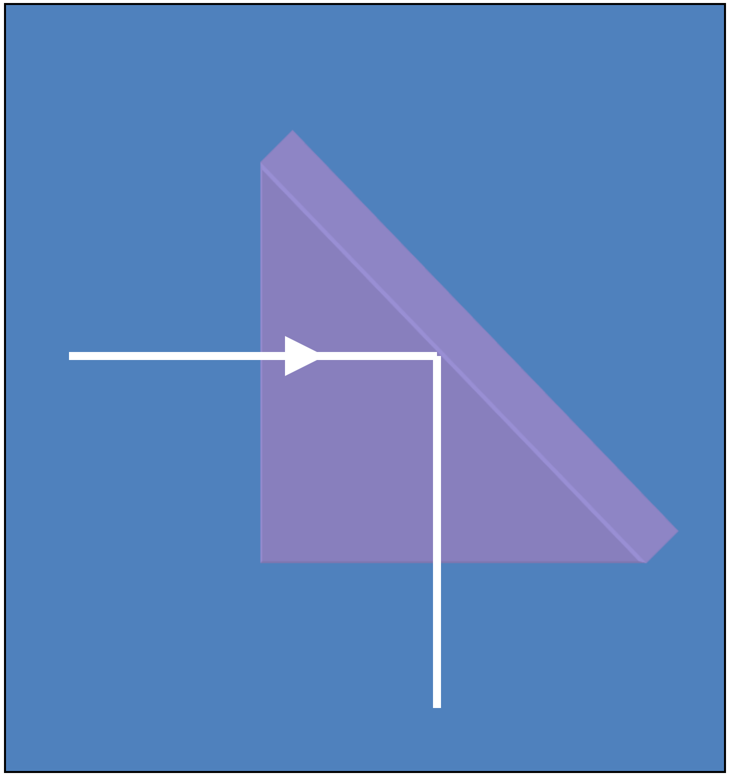
$$n = 1.66$$

Critical angle – Example 3

Material	Refractive index	Critical angle
Glass	1.5	42°
Water	1.33	49°
Diamond	2.4	24°

The greater the refractive index, the smaller the critical angle.

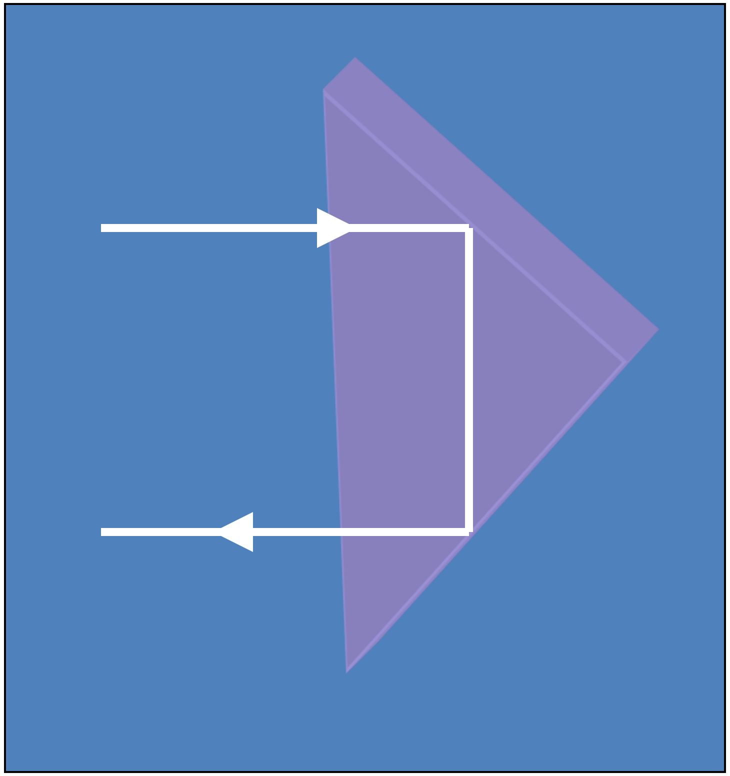
Using TIR



A right angled prism will bend light through 90°.

Two of these prisms can be used to produce a periscope.

Back the way they came

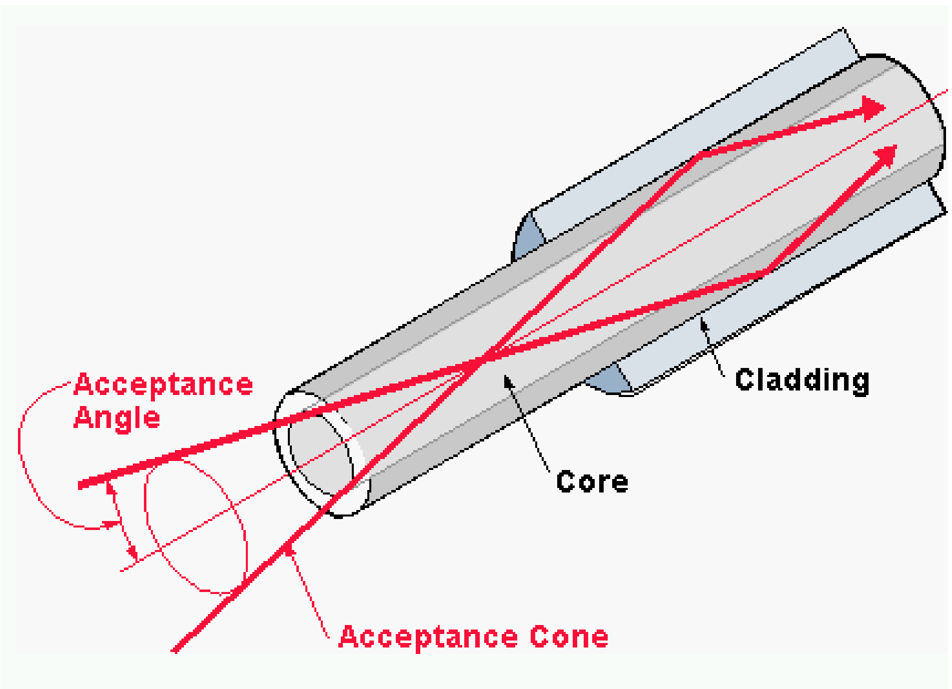


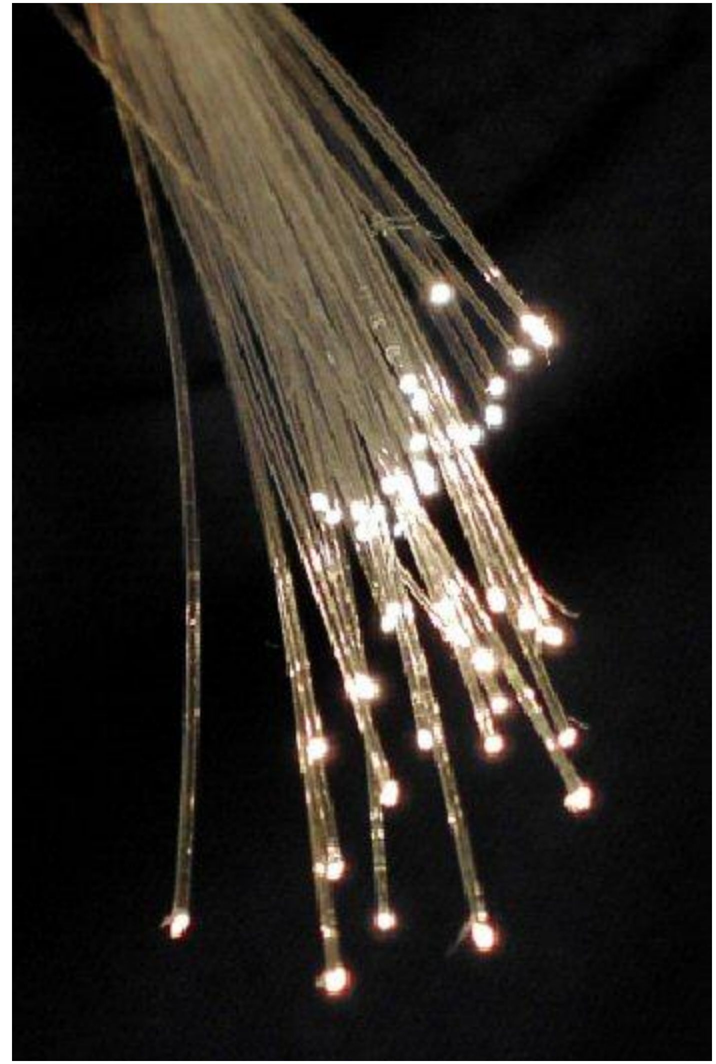
A right angled prism will also bend light through 180°.

This idea is used in reflective clothes and signs.

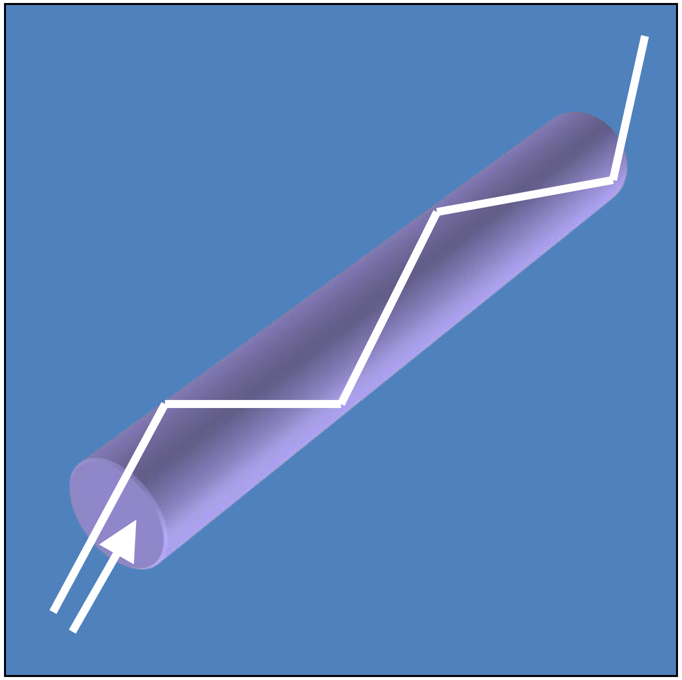
Fibre optics

Fiber Optics



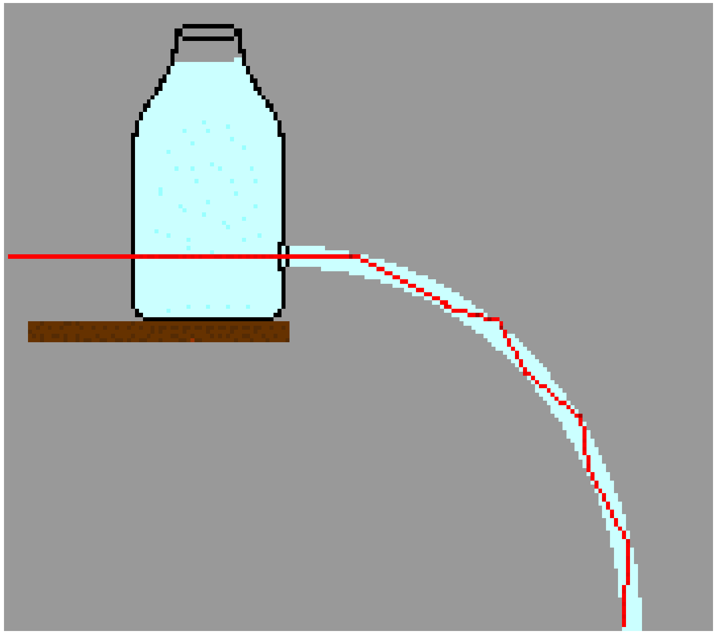


Optical fibres

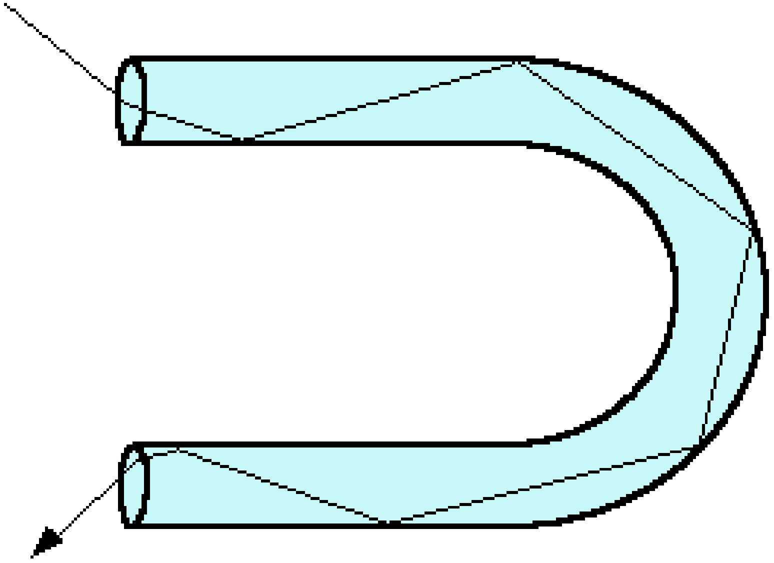


Light is refracted as it enters the fibre.

Every time it tries to leave it is reflected back inside.



The laser beam stays internal to the water, continuously reflecting at each boundary.

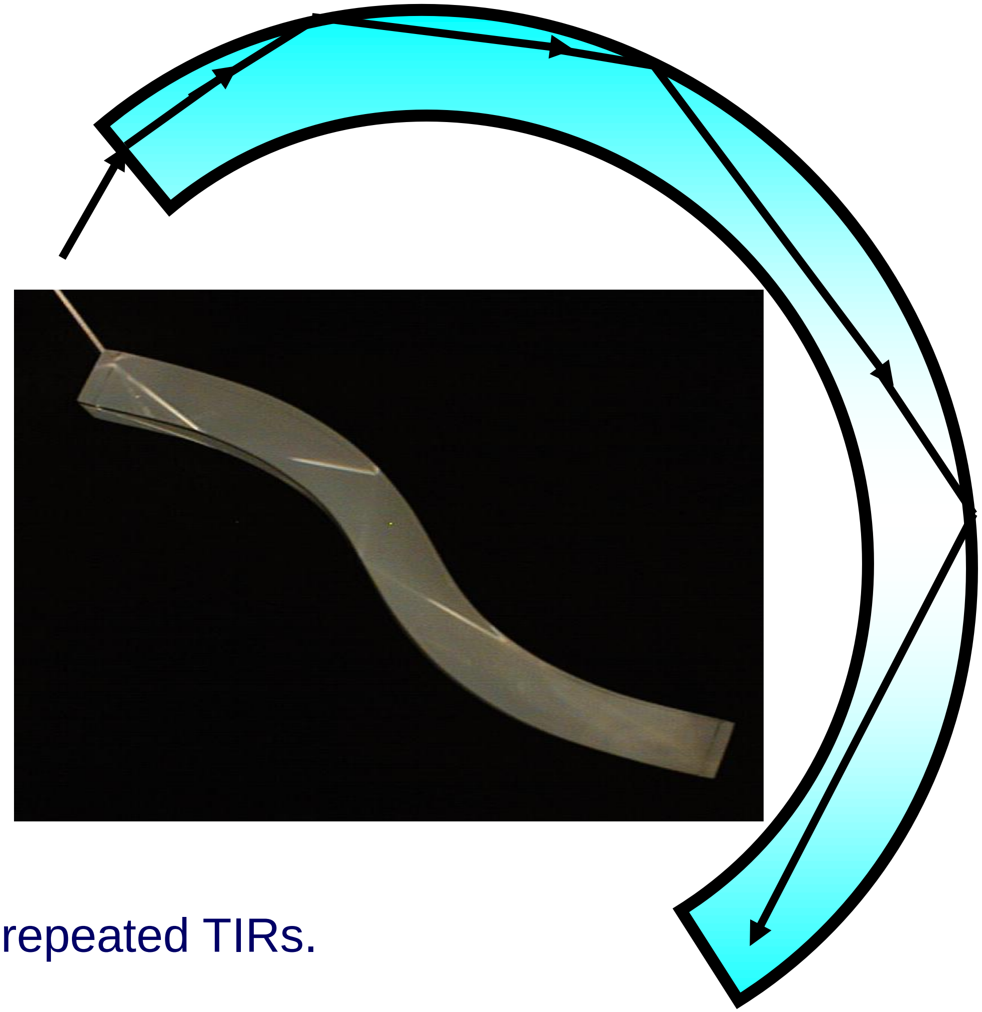


The light is always reflected back into the material and does not escape. Total internal reflection is used to send signals along fibre optic cables for the Internet and TV.

What are the applications of total internal reflection (TIR)?

Optical fibres, used in communication, use TIR.

You could be asked to draw on the path of the beam in an exam.

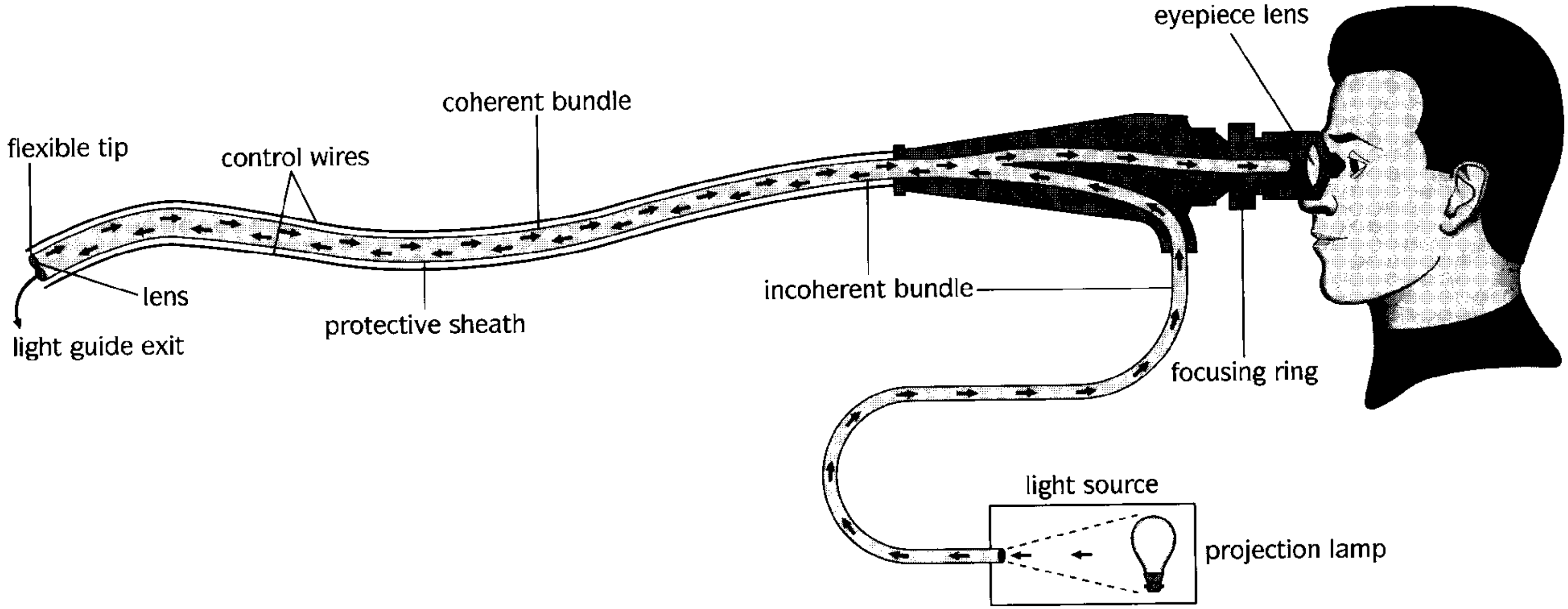


1. A beam of light enters the optical fibre.

2. It is refracted as it enters the fibre.

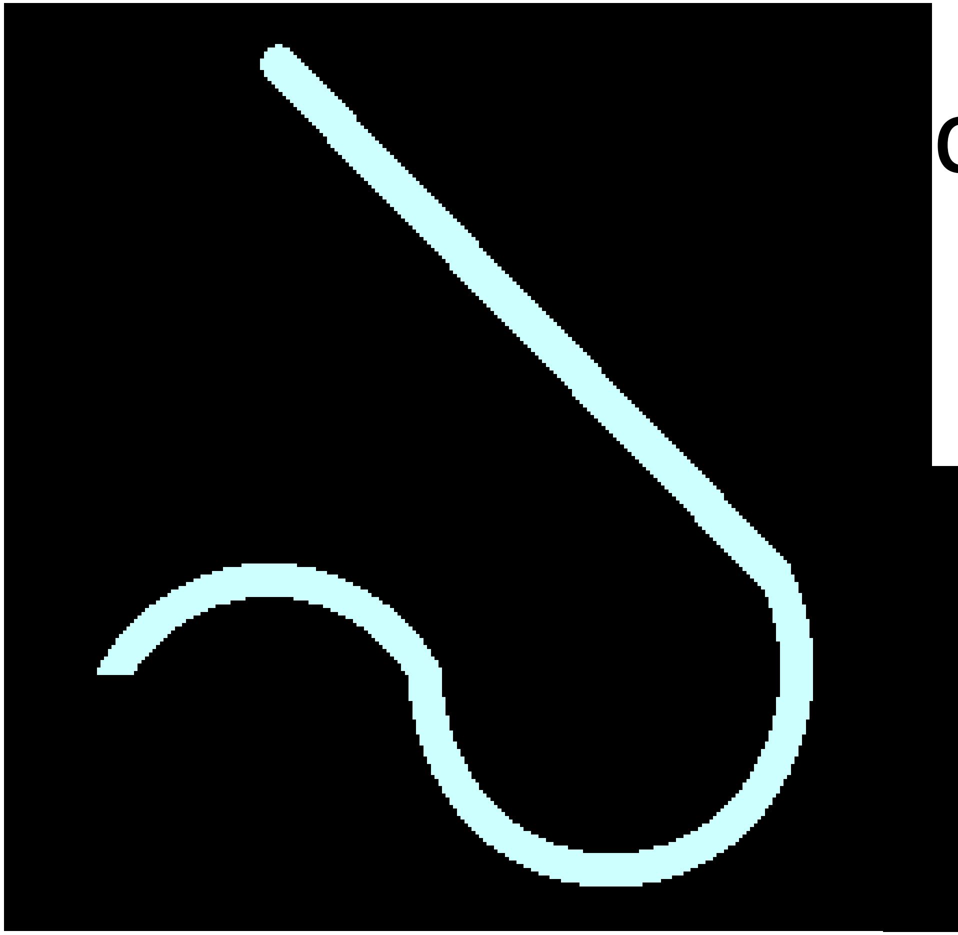
3. It travels down the fibre through repeated TIRs.

Endoscope



An endoscope uses total internal reflection to enable a doctor to look deep inside the body. It enables key hole surgery to take place.

c cable



thin piece of glass

critical angle total internal reflection

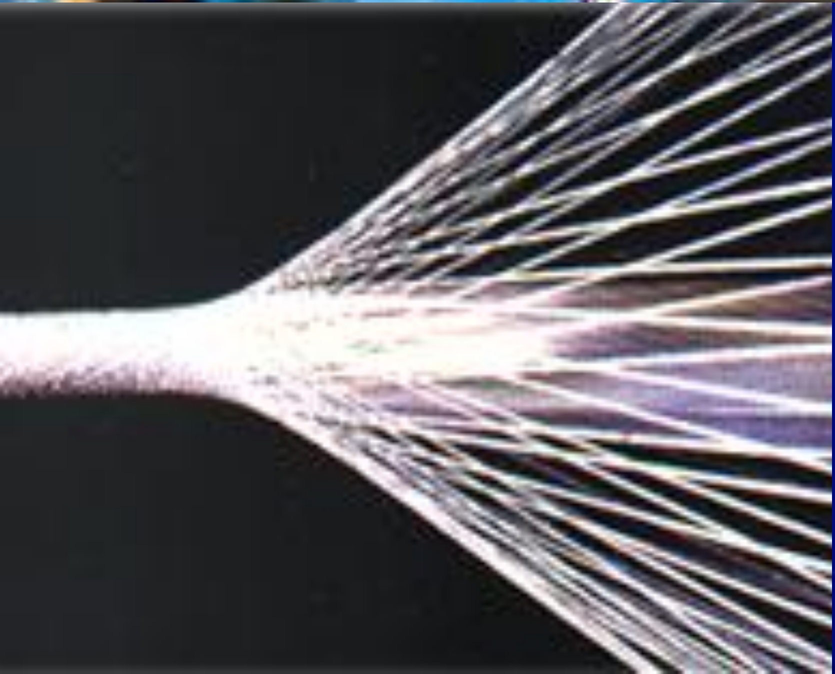
Advantages of Fibre optics

- Low attenuation (signal loss) of wave means they can go further.
- Small diameter of fibre for a high capacity channel.
- Low cost of materials.
- Cables may be non-conducting so no shocks.
- High Security, it is hard to listen in on an optical fibre.

Disadvantages of Fibre optics

- Need for additional conducting members in cable when electrical supplies are required for remote terminals.
- They can be damaged by some ionising radiations.
- Electrical cables are already in place.
- Fibres not directly suited to multiple-access use.


ALCATEL




Summary – TIR and optical fibres

- When light passes out of a material it can be internally reflected. Refractive index and critical angle are connected by a formula: $\sin(c) = 1/n$

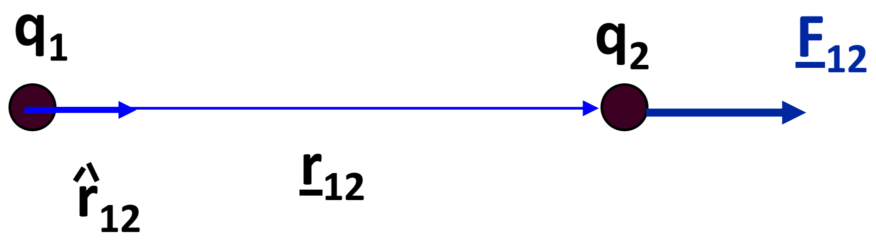
- Optical fibres are thin pieces of glass or plastic that light can travel through whilst being totally internally reflected.

Electrostatics

Summary of Electric Charge:

- There is a property of matter called electric charge. (In the SI system its units are Coulombs.)
- Charges can be negative (like electrons) or positive (like protons).
- In matter, the positive charges are stuck in place in the nuclei. Matter is negatively charged when extra electrons are added, and positively charged when electrons are removed.
- Like charges repel, unlike charges attract.
- Charges travel in conductors, not in insulators
- Force of attraction or repulsion $\sim 1 / r^2$

Coulomb's Law



$$\underline{\mathbf{F}}_{12} = \frac{k q_1 q_2}{r_{12}^{\ 2}} \hat{\mathbf{r}}_{12}$$

Force on 2 due to 1

$k = (4\pi\varepsilon_0)^{-1} = 9.0 \times 10^9\ \text{Nm}^2/\text{C}^2$

ε_0 = permitivity of free space

$= 8.86 \times 10^{-12}\ \text{C}^2/\text{Nm}^2$

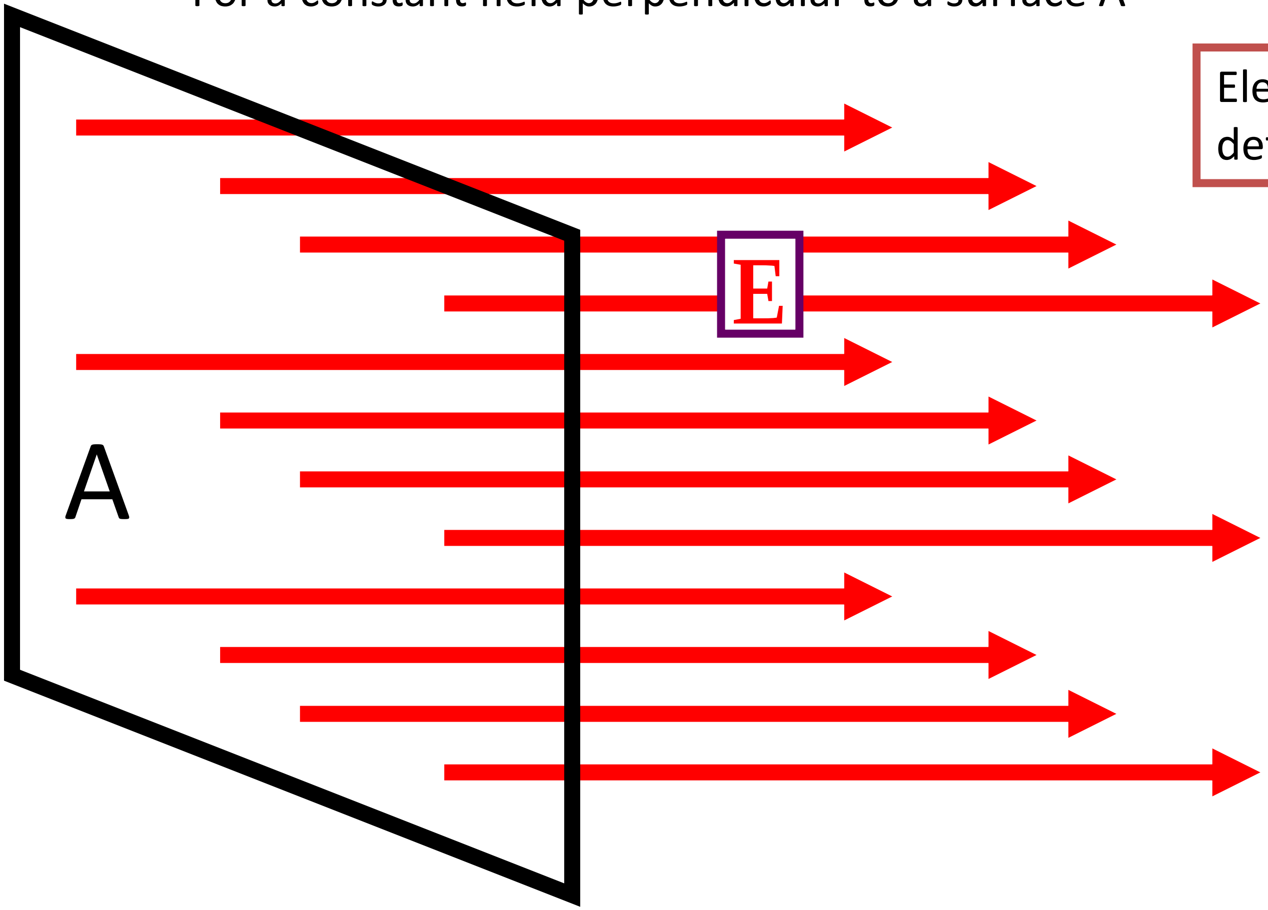
Coulomb's law describes the interaction between bodies due to their charges

Electric potential

- When a small electric charge is placed in the electric field due to another charge, it experiences a force. So, work has to be done on the positive charge to move it against this force of repulsion.
- The electric potential is defined as the work done in moving a unit positive charge fro infinity to that point.

Electric Flux:
Field Perpendicular

For a constant field perpendicular to a surface A



Electric Flux is defined as

$$\Phi = |\mathbf{E}|\, A$$

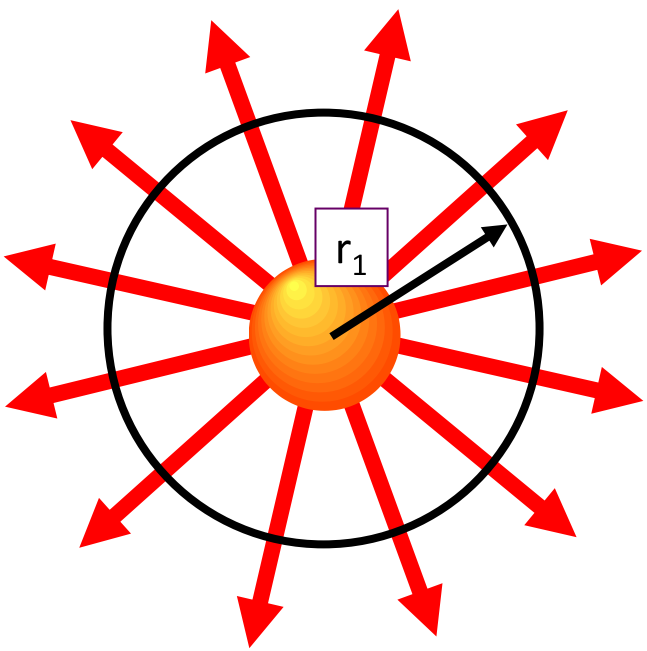
Gauss's Law

Relates flux through a closed surface
to
charge within that surface

Flux through a sphere from a point charge

The electric field around a point charge

$$|\mathbf{E}| = \frac{1}{4\pi\varepsilon_0}\frac{Q}{|\mathbf{r}_1|^2}$$



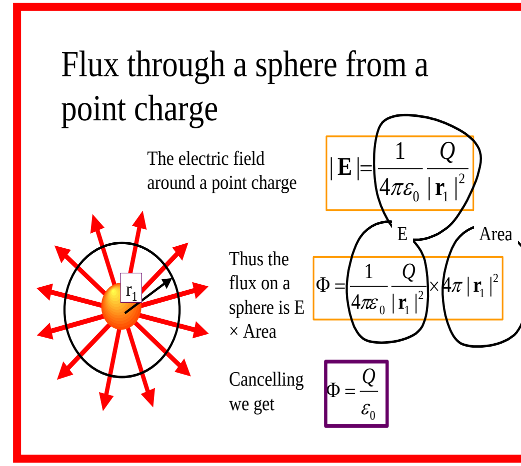
Thus the flux on a sphere is E × Area

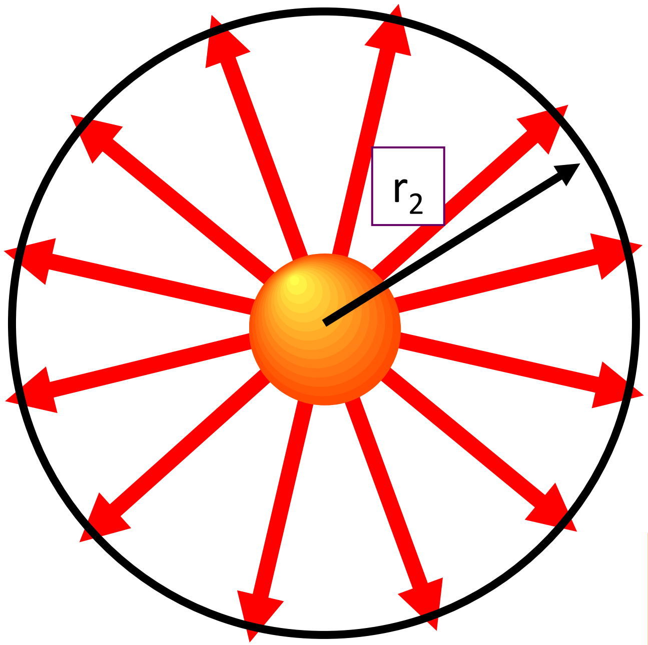
$$\Phi = \frac{1}{4\pi\varepsilon_0}\frac{Q}{|\mathbf{r}_1|^2}\times 4\pi|\mathbf{r}_1|^2$$

Cancelling we get

$$\Phi = \frac{Q}{\varepsilon_0}$$

Now we change the radius of sphere





$$|\mathbf{E}| = \frac{1}{4\pi\varepsilon_0}\frac{Q}{|\mathbf{r}_2|^2}$$

$$\Phi_2 = \frac{1}{4\pi\varepsilon_0}\frac{Q}{|\mathbf{r}_2|^2} \times 4\pi|\mathbf{r}_2|^2$$

$$\Phi_2 = \frac{Q}{\varepsilon_0}$$

The flux is the same as before

$$\Phi_2 = \Phi_1 = \frac{Q}{\varepsilon_0}$$

Flux lines & Flux

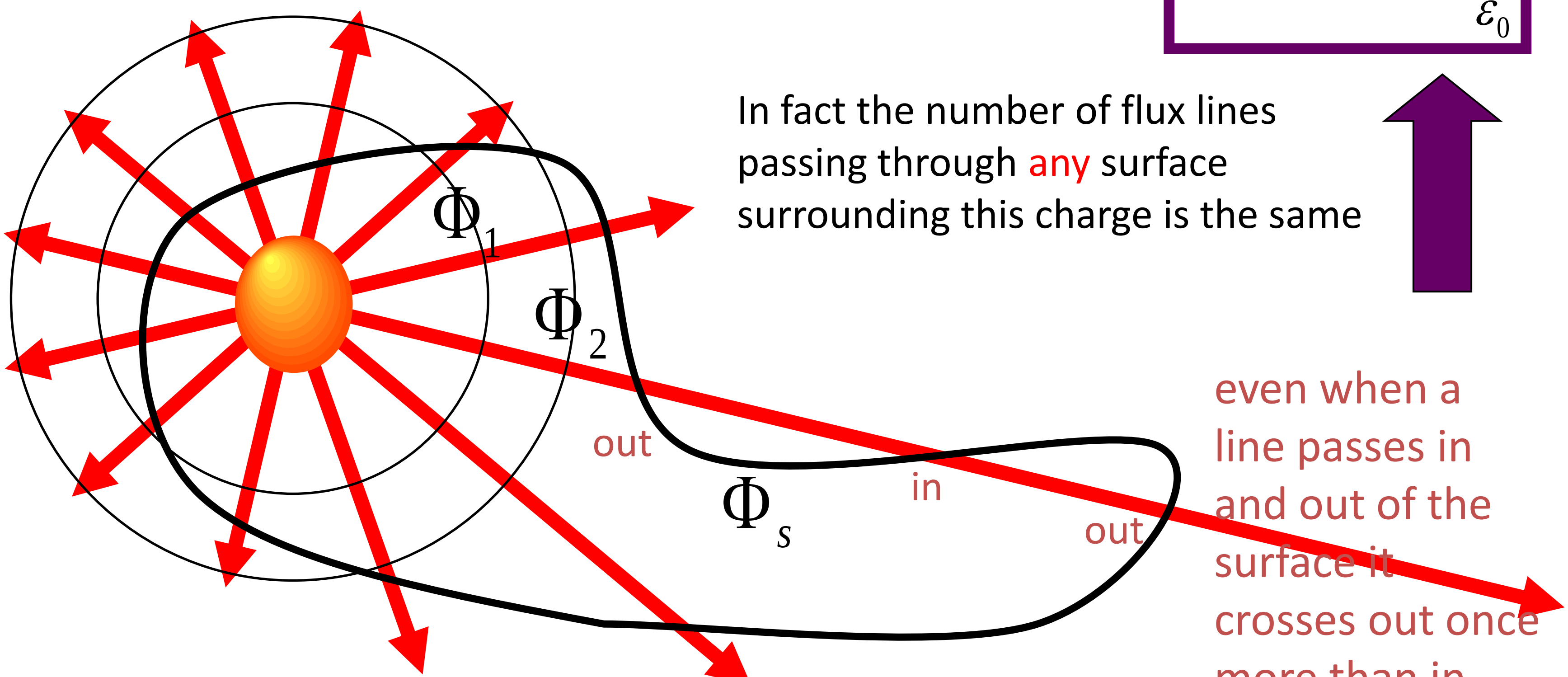
Just what we would expect because the number of field lines passing through each sphere is the same

$$N \propto \Phi \qquad \Phi \propto N$$

and number of lines passing through each sphere is the same

$$\Phi_S = \Phi_2 = \Phi_1 = \frac{Q}{\varepsilon_0}$$

In fact the number of flux lines passing through any surface surrounding this charge is the same



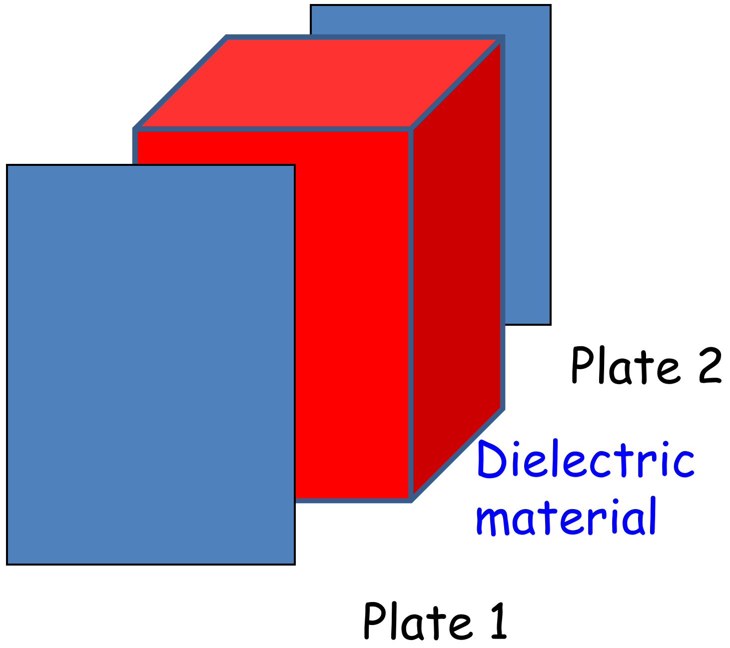
even when a line passes in and out of the surface it crosses out once more than in

Capacitors

- A basic capacitor has two parallel plates separated by an insulating material
- A capacitor stores an electrical charge between the two plates
- The unit of capacitance is Farads (F)
- Capacitance values are normally smaller, such as µF, nF or pF

Capacitors

- Basic capacitor construction

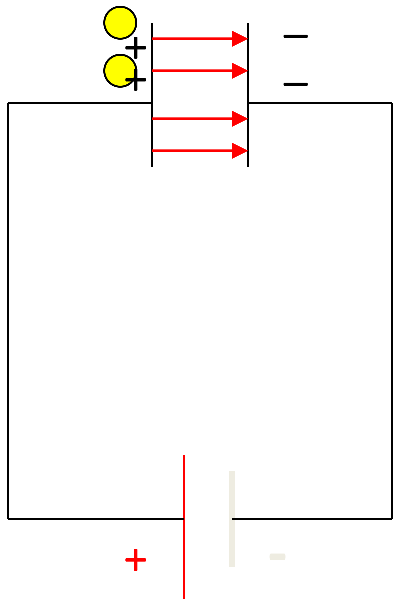


The dielectric material is an insulator therefore no current flows through the capacitor

Capacitors

Storing a charge between the plates

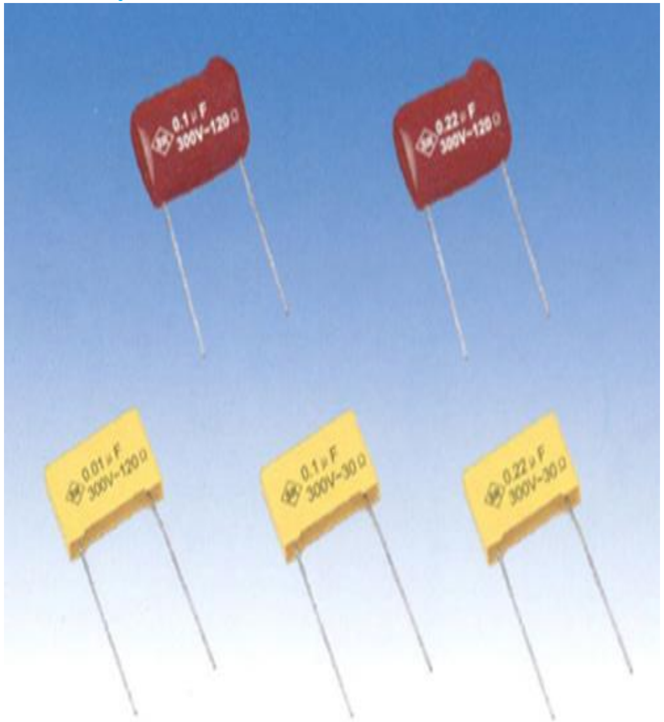
- Electrons on the left plate are attracted toward the positive terminal of the voltage source
- This leaves an excess of positively charged holes
- The electrons are pushed toward the right plate
- Excess electrons leave a negative charge

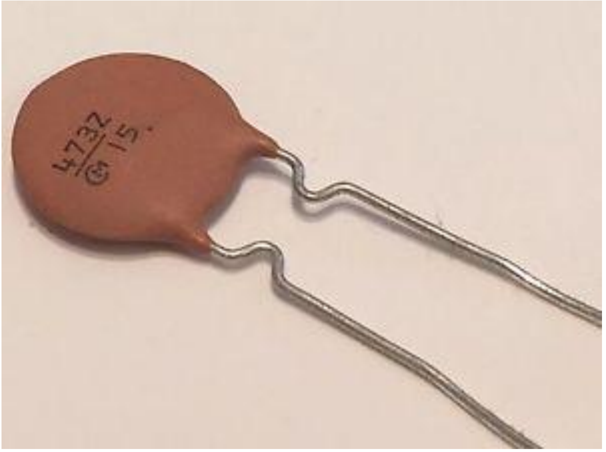


Capacitors

Types of capacitors

- The dielectric material determines the type of capacitor

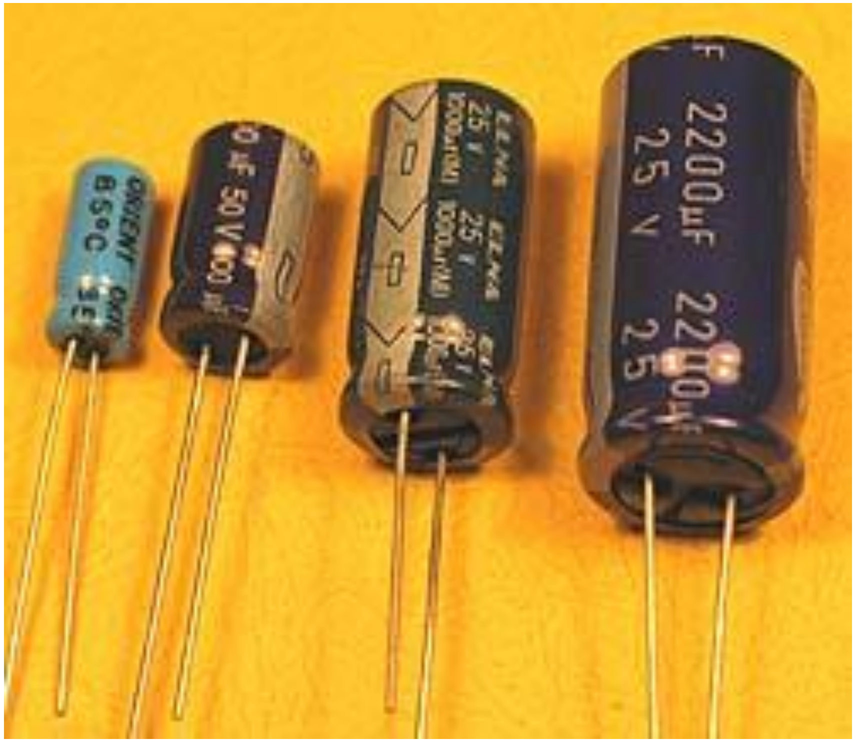




- Common types of capacitors are:
  - Ceramic
  - Mica
  - Plastic film

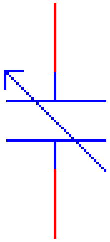
Capacitors

- Some capacitors are polarised, they can only be connected one way around
- Electrolytic capacitors are polarised



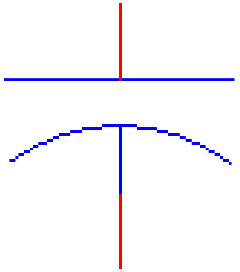
Capacitors

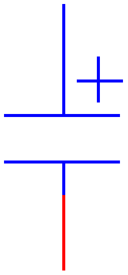
- Variable capacitors are used in communication equipment, radios, televisions and VCRs
- They can be adjusted by consumers by tuning controls



Markings of capacitor

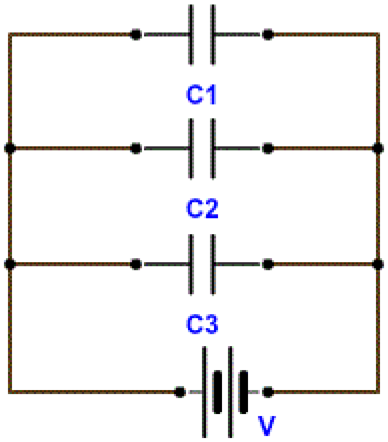
- Consider a ‘6.3V 1500μF’ capacitor shown in the following figure. Note that:
  - Maximum voltage across the capacitor should not exceed 6.3 V, otherwise (leakage or) breakdown may occur.
  - Capacitance of 1500μF means the capacitor holds 1500μC of charge for every 1 V of voltage across it.





Capacitors in Parallel

- In parallel combination of Capacitors, each capacitor has same potential difference but different charge
- So in parallel effective capacitance increases



$$Q = Q_1 + Q_2 + Q_3$$

$$Q = C_p V$$

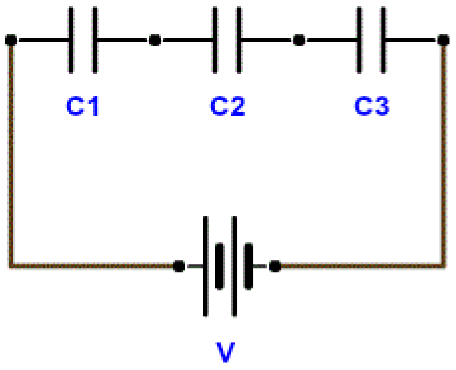
$$Q_1 = C_1 V,\ Q_2 = C_2 V,\ Q_3 = C_3 V$$

$$C_p V = C_1 V + C_2 V + C_3 V$$

$$C_p = C_1 + C_2 + C_3 = \sum C_i$$

Capacitors in Series

- In series combination of capacitors, each capacitor has same charge but different potential difference



$$V = V_1 + V_2 + V_3$$

$$V = \frac{Q}{C_s}$$

$$V_1 = \frac{Q}{C_1}$$

$$V_2 = \frac{Q}{C_2}$$

$$V_3 = \frac{Q}{C_3}$$

$$\frac{Q}{C_s} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$$

$$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$\frac{1}{C_s} = \sum_{i=1}^{n} \frac{1}{C_i}$$

Thanks for your attention…!!!

Any Queries ??

UNIT - 5

ELECTROMAGNETISM

The branch of Physics that contains studies about the forces occurring between electrically charged particles is called electromagnetism.

Two aspects of electromagnetism are :-

*** Electricity**
*** Magnetism**

ELECTRICITY

comes from the moving charge. Means whenever a charge flows it makes electric current and its effects are studied under current electricity.

MAGNETISM

A force of attraction or repulsion that acts at a distance and caused due to a magnetic field is called magnetism.

***Flowing electrons cause magnetic field.**
***Spinning magnets cause electric current to flow.**

SO

There is a relation between electricity and magnetism (Called ELECTROMAGNETISM)

Magnetic Field

A force field that is created by moving electric charges and magnetic dipoles is called magnetic field.

Applications of electromagnetism

1. It is used in home appliances like Electric fan, electric motor, electric door bell etc.
2. It is used in computer hardware.
3. It is used in electronic storage devices.
4. It is used in power circuits.
5. It is used in communication device
6. It is used in microwaves.

Magnetic Force

The attraction or repulsion that arises between electrically charged particles because of their motion is called magnetic force.

Magnetic Materials

The materials which are attracted or repelled when placed in an external magnetic field are called magnetic material. *Iron, Cobalt, Nickel, Manganese* etc. are examples of magnetic materials.

Magnetic Susceptibility

It is
A dimensionless proportionality constant that indicates the degree of magnetization of a material in response to a magnetic field .

Magnetic permeability

It is the measure of the ability of a material to support the magnetic field within itself. Thus it is degree of magnetization obtained by material in response to applied magnetic field.

Three types of magnetic materials

1. Diamagnetic Materials
2. Paramagnetic Material
3. Ferromagnetic Material

Diamagnetic Material

They repel the externally applied magnetic field. All electrons within atoms of diamagnetic material are paired so they do not generate their own net magnetic field.

Diamagnetic material become weakly magnetized in a direction opposite to the applied field.
Examples of diamagnetic material are

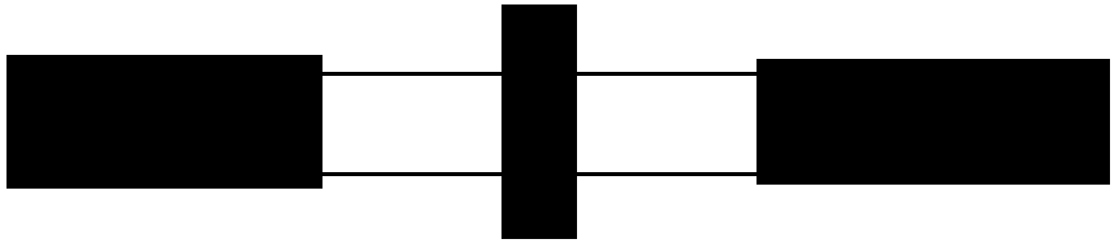
* Copper
* Gold
* Mercury
* Water
* antimony etc.

Properties of Diamagnetic material

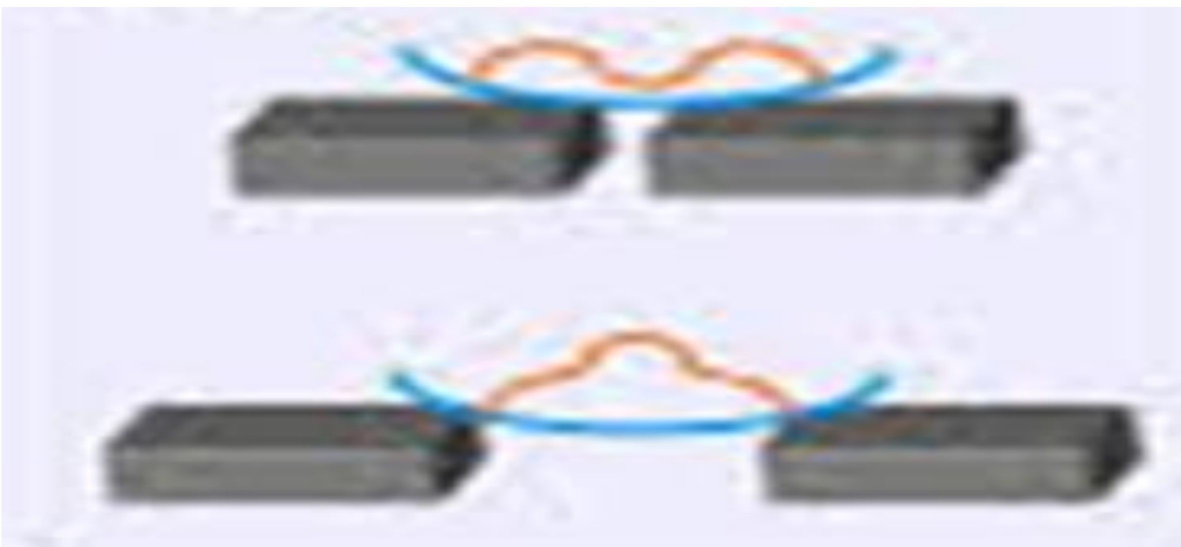
1. They are repelled by a magnet.
2. They do not obey curie law.
3. If placed in external magnetic field, it gets magnetized in opposite direction to applied field.
4. They have negative susceptibility.

5. When placed in a non uniform magnetic field, it tends to move from stronger to weaker region.
6. The permeability of diamagnetic substance is less than one.
7. As soon as the magnetic field is removed, it looses its magnetism.

8.The rod of diamagnetic material suspended in external magnetic field sets itself at right angles to magnetic field slowly.



9. The diamagnetic liquid contained in a watch glass, placed on two closely placed pole pieces of a magnet , shows depression at center .If poles are moved away, it collects at center.



Paramagnetic material

These are materials which are weakly attracted by an externally applied magnetic field.

Examples are

*** Magnesium**

*** Lithium**

*** Tantalum**

*** Molybdenum**

Properties of Paramagnetic material

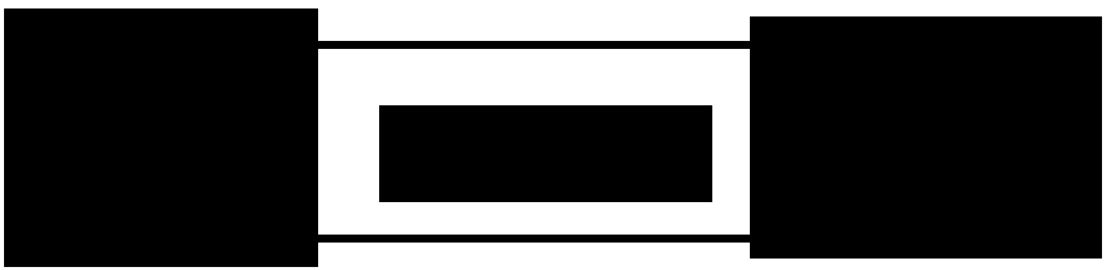
1. They are attracted by a magnet.
2. They develop weak magnetization along the direction of applied magnetic field.
3. They move from weaker to stronger part of magnetic field.
4. They obey curie law.

5. They tend to loose their magnetism on rise in temperature.

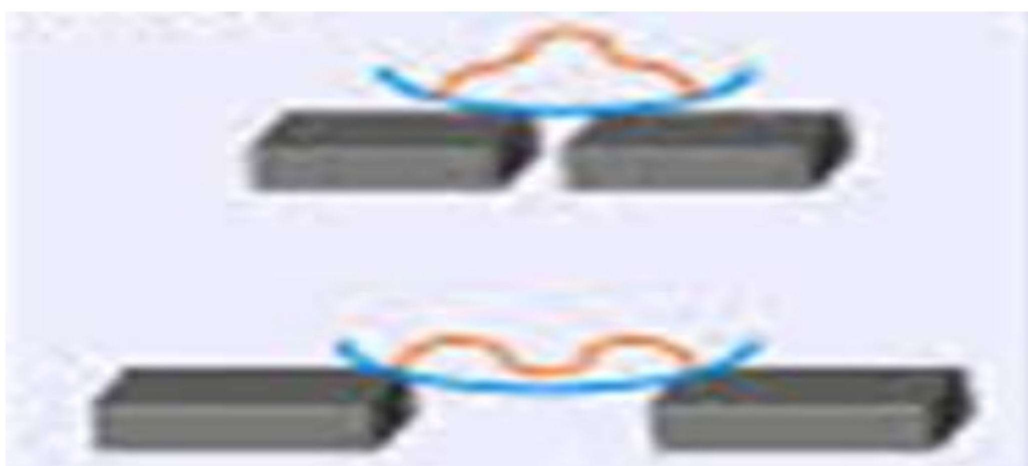
6. Their magnetic permeability is slightly greater than one.

7. They have small positive susceptibility.

8.The rod of paramagnetic material suspended in external magnetic field aligns itself in the direction of magnetic field slowly.



9. The paramagnetic liquid contained in a watch glass, placed on two closely placed pole pieces of a magnet , shows rise in middle. If poles are moved away, it collects at edges.



Ferromagnetic material

These materials are strongly attracted by magnet and can be magnetized. The cause of magnetization for these substance is formation of domains. Examples are

*** Iron**

*** Cobalt**

*** Nickel**

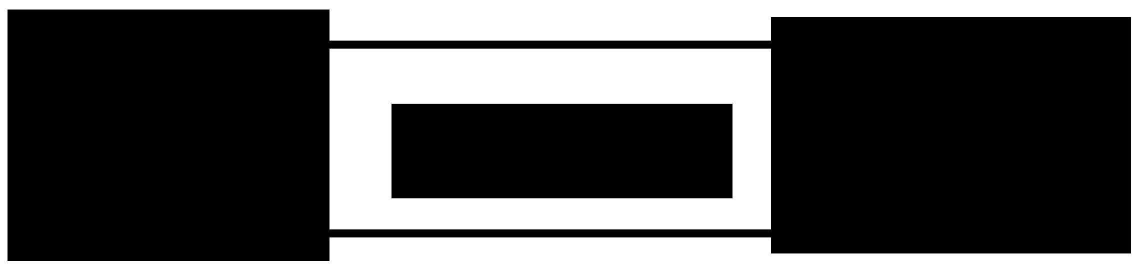
Ferromagnetic material have some unpaired electrons, so their atoms have a net magnetic moment

Properties of Ferromagnetic material

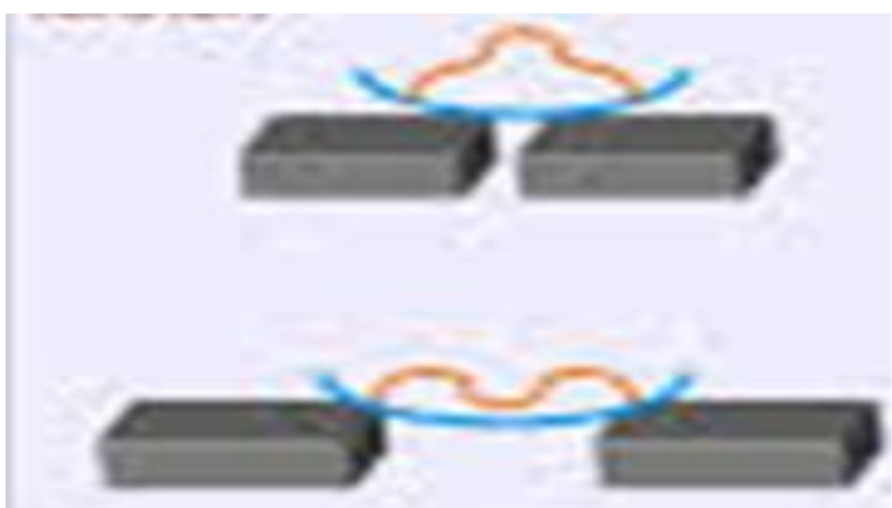
1. They are strongly attracted by a magnet.
2. They develop strong magnetization along the direction of applied magnetic field and become a powerful magnet.
3. They move from weaker to stronger part of magnetic field.

4. Ferromagnetism decreases with rise in temperature.
5. The magnetic permeability for them is greater than one and prominent.
6. They have high value of susceptibility.
7. They become paramagnetic above curie temperature.

8.The rod of ferromagnetic material suspended in external magnetic field rapidly aligns itself in the direction of magnetic field.



9. The ferromagnetic liquid contained in a watch glass, placed on two closely placed pole pieces of a magnet , collects at center quickly. If poles are moved away, it collects at edges



10. They can retain magnetism. ie If external field is removed they show residual magnetism.
11. They obey curie law.
12. Ferromagnetism is not found in liquids and gases.

Curie Temperature :-

The temperature above which the ferromagnetic material turns into paramagnetic material is called Curie Temperature. It is different for different materials.

Values of curie temperature for different materials are as follows

Iron	1043 K
Nickel	627 K
Cobalt	1388 K
Gadolinium	293K

Magnetic field Intensity

It is the magneto motive force per unit length. It is the force experienced by a unit north pole at the point and its direction is the direction in which the pole moves if free to do so.

Magnetic field intensity is denoted by H. It is a vector quantity. Its SI unit is A/m (ampere per meter).

Mathematically

$$H = F / l$$

Magnetic lines of force

They are the imaginary lines resenting the direction of magnetic field. The tangent drawn at any point to these lines gives the direction of field vector at that point. Their density at any point gives magnitude of field.

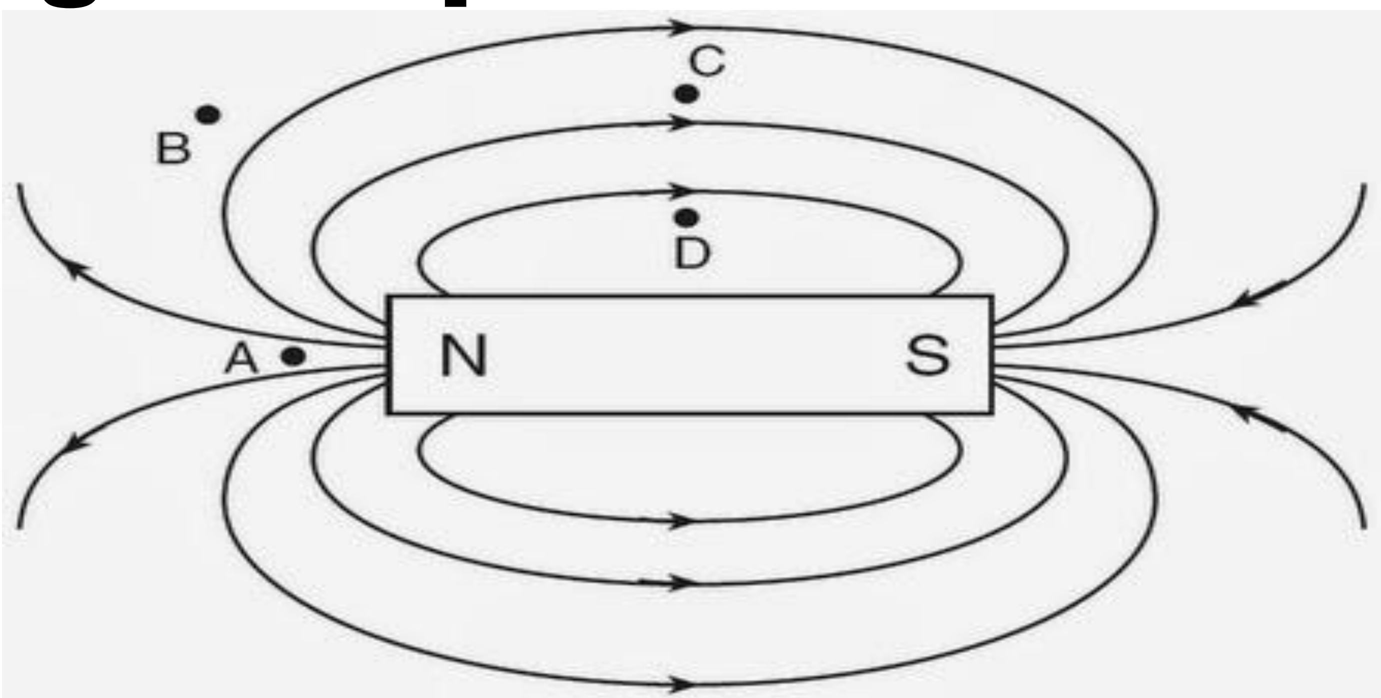
Properties of magnetic lines of force

1. They are closed and continuous curves. They travel from north pole to south pole outside the magnet and south pole to north pole inside the magnet. They do not have any origin or end.

2. They do not interact each other.
3.They can emerge north pole at any angle and can merge into south pole at any angle.
4.They are crowded near pole and distended from magnet as you move away from pole.
5. They never cross each other.

6. Thy all have the same strength.

7. They seek the path of least resistance between opposite magnetic poles.



Magnetic flux

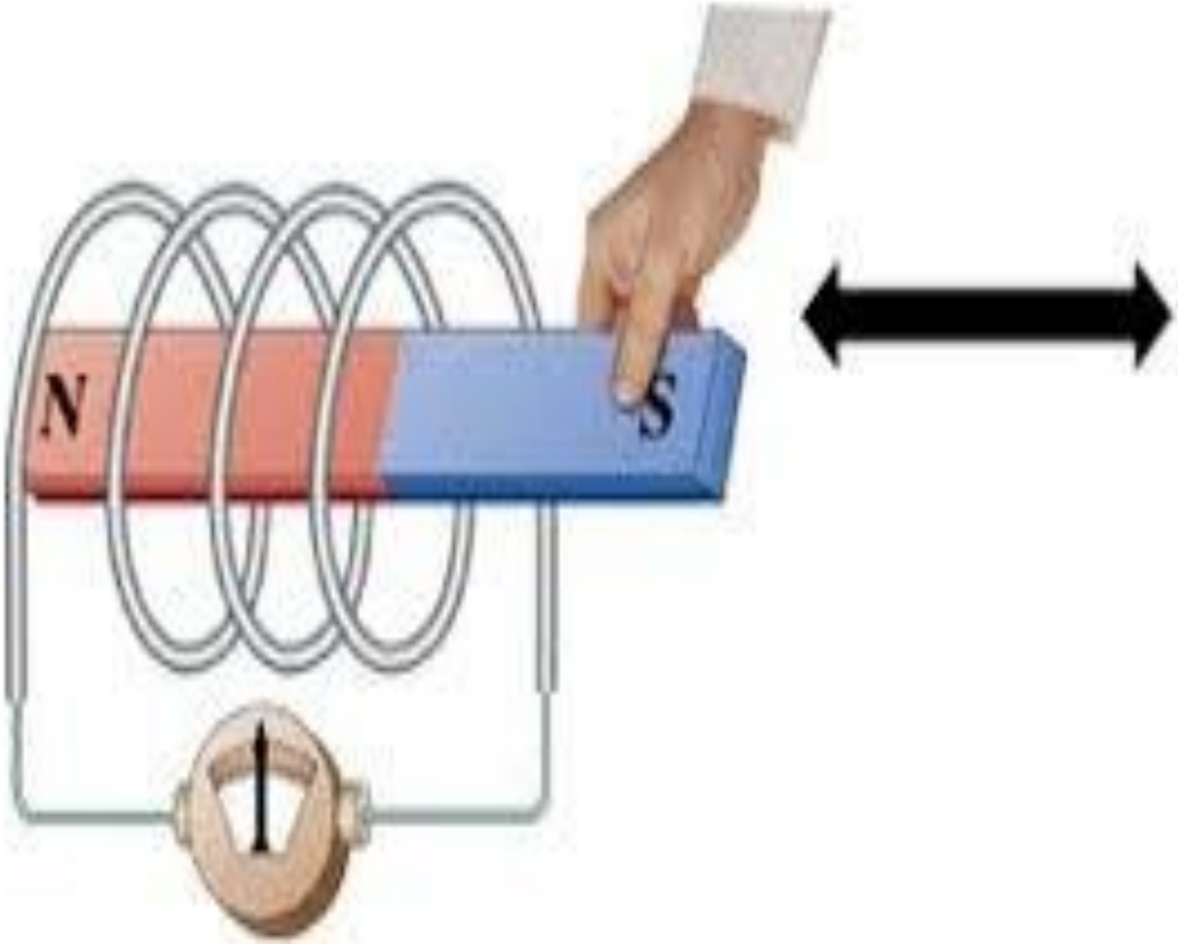
The number of magnetic lines of forces set up in magnetic circuit is called magnetic flux.
It is denoted by ϕ.
Its SI unit is Weber (wb).

Mathematically magnetic flux is the dot product of magnetic field B and surface vector S. ie

$$\phi = \mathbf{B}.\mathbf{S}$$

Electromagnetic Induction

**is the production of
an electromotive force(i.e., voltage) across an electrical conductor in a changing magnetic field**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Applications of Electromagnetic Induction

The principles of electromagnetic induction are applied in many devices and systems like -

* Current clamp
* Electric generators
* Electromagnetic forming
* Graphics tablet
* Magnetic flow meters   etc.

THANK YOU

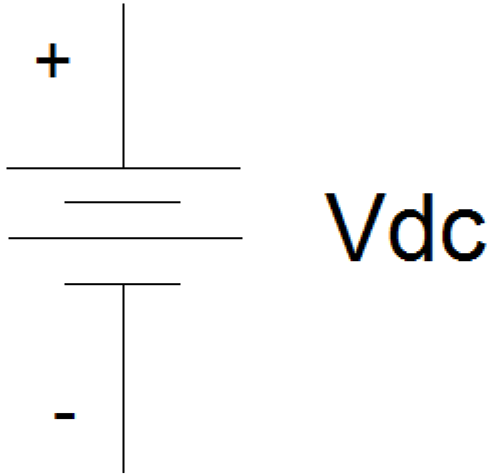
Current Electricity

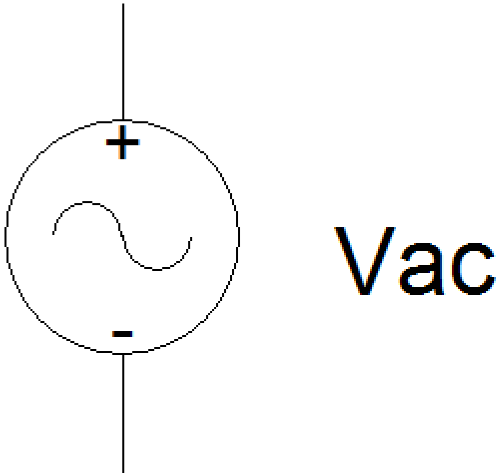
DC vs. AC

- DC (or dc) is the acronym for direct current.
  - The current remains constant with time.
    - Uppercase variables are used when calculating dc values.
- AC (or ac) is the acronym for alternating current.
  - Specifically, AC current varies sinusoidally with time and the average value of the current over one period of the sinusoid is zero.
    - Lowercase variables are used when calculating ac values.
  - Other time-varying currents exist, but there isn't an acronym defined for them.

Ideal Voltage Sources

- Independent voltage source outputs a voltage, either dc or time varying, to the circuit no matter how much current is required.





Current

- The flow of charge through a cross-sectional area as a function of time or the time rate of change of charge
- Symbol used is I or i

$$i = \frac{dq}{dt}; \qquad I = \frac{\Delta Q}{\Delta t}$$

$$Q = \int_{t_1}^{t_2} i\, dt; \quad Q = I(t_2 - t_1)$$

Resistance, R

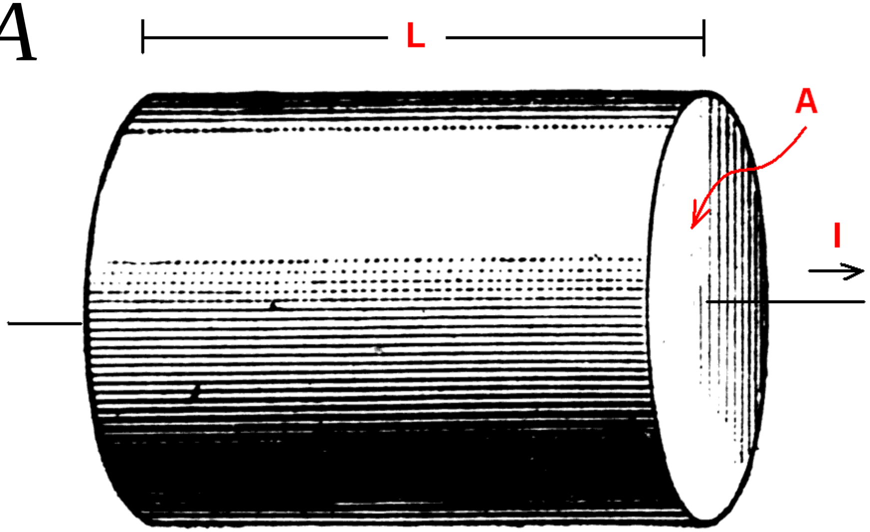
- Resistance takes into account the physical dimensions of the material

$$R = \rho \frac{L}{A}$$

where:

L is the length along which the carriers are moving

A is the cross sectional area that the free charges move through.



Conductance, G

- Conductance is the reciprocal of resistance

$$G = R^{-1} = i/v$$

Unit for conductance is S (siemens) or $\mho$ (mhos)

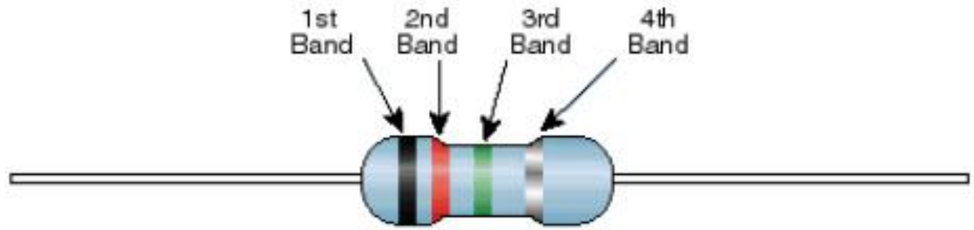
$$G = A\sigma/L$$

where σ is conductivity,

which is the inverse of resistivity, ρ

4 Band Color Code

Standard EIA Color Code Table **4 Band**: ±2%, ±5%, and ±10%



Color	1st Band (1st figure)	2nd Band (2nd figure)	3rd Band (multiplier)	4th Band (tolerance)
Black	0	0	10^0	
Brown	1	1	10^1	
Red	2	2	10^2	±2%
Orange	3	3	10^3	
Yellow	4	4	10^4	
Green	5	5	10^5	
Blue	6	6	10^6	
Violet	7	7	10^7	
Gray	8	8	10^8	
White	9	9	10^9	
Gold			10^{-1}	±5%
Silver			10^{-2}	±10%

Action-Electronics.com

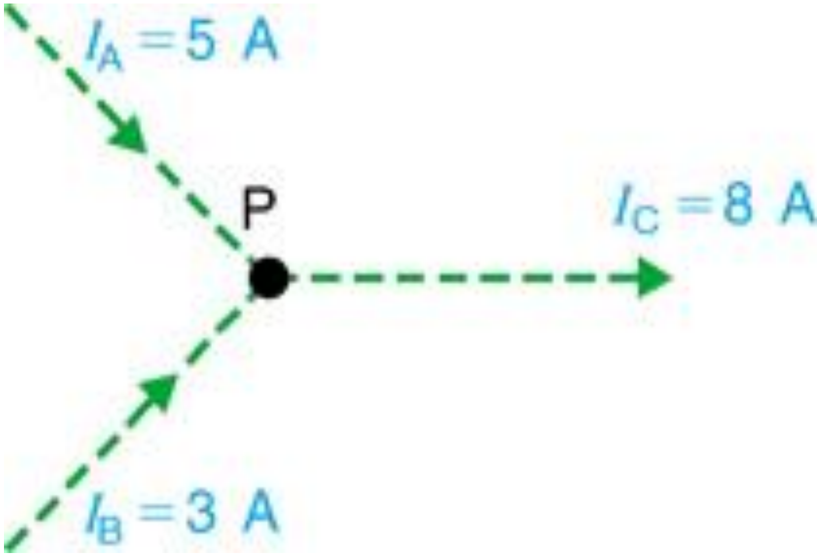
Kirchhoff's Current Law (KCL)

– The sum of currents entering any point in a circuit is equal to the sum of currents leaving that point.

– Otherwise, charge would accumulate at the point, reducing or obstructing the conducting path.

– Kirchhoff's Current Law may also be stated as

$I_{IN} = I_{OUT}$



Current *IC* out from point P equals 5A + 3A into P.

Kirchhoff's Current Law (KCL)

The 6-A I_T into point C divides into the 2A (I_3) and 4A ($I_{4\text{-}5}$)

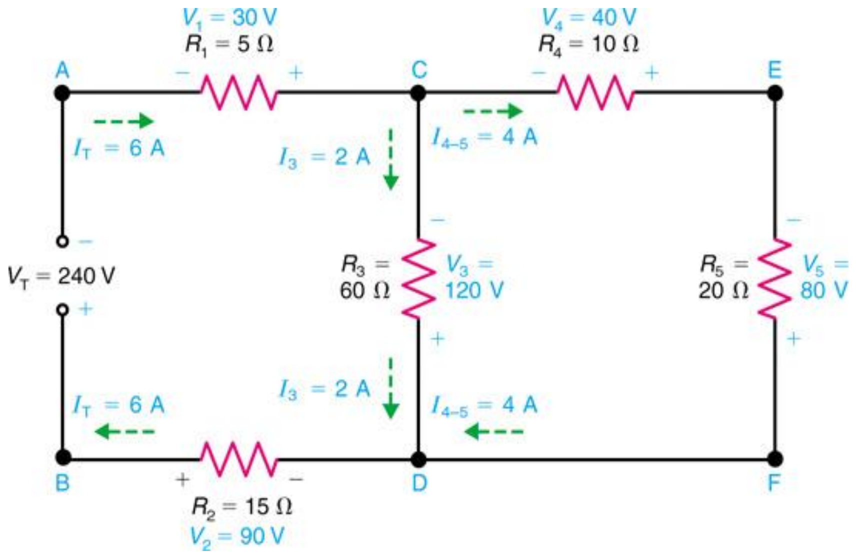
$I_{4\text{-}5}$ is the current through R_4 and R_5

$$I_T - I_3 - I_{4\text{-}5} = 0$$

$$6A - 2A - 4A = 0$$

At either point C or point D, the sum of the 2-A and the 4-A branch currents must equal the 6A line current.

Therefore, $I_{in} = I_{out}$



Kirchhoff's Voltage Law (KVL)

- In a closed loop sum of voltage Gains is equal to sum of Voltage drops

$$\sum V_{Gain} = \sum V_{Drop}$$

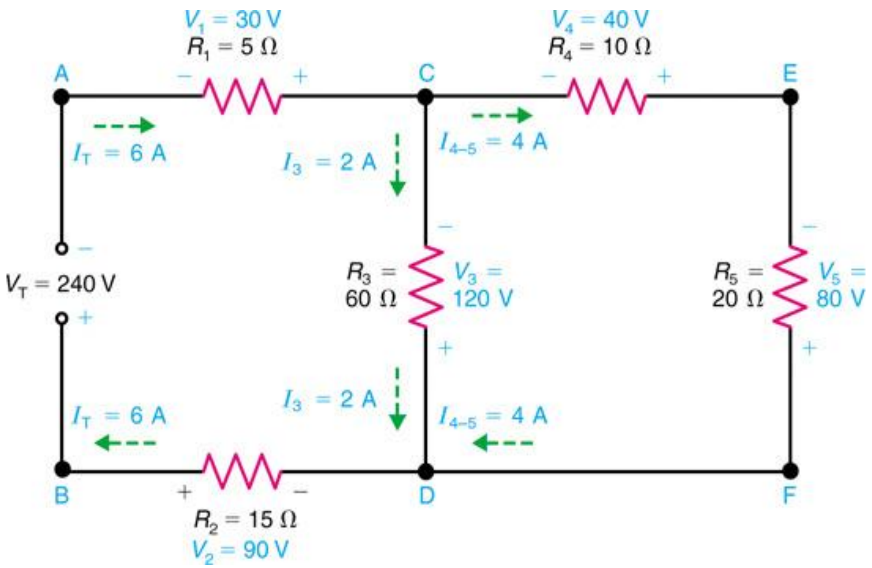
- Loop Equations
  - A **loop** is a closed path.
  - This approach uses the algebraic equations for the voltage around the loops of a circuit to determine the branch currents.
    - Use the *IR* drops and KVL to write the loop equations.
    - A loop equation specifies the voltages around the loop.

Kirchhoff's Voltage Law (KVL)

In Figure for the inside loop with the source V_T, going counterclockwise from point B,

90V + 120V + 30V = 240V

The loop equations show that KVL is a practical statement that the sum of the voltage drops must equal the applied voltage.



Electric Power

$P = W / t$
(Power=Work/time)

Remember: $W = Vq$ and $I = q/t$

So: $P = I V$

P: is the power consumed by a resistor, R.

kWh

kiloWatt hour

What does the kWh measure,

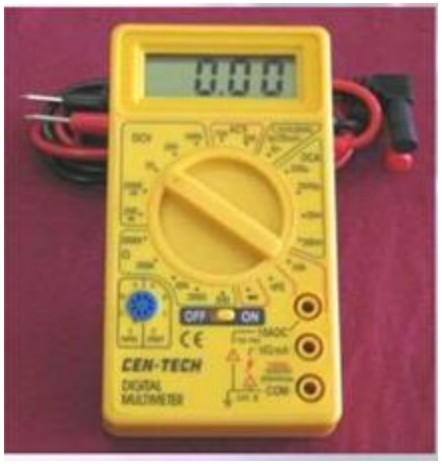
a) Energy

b) Power ?

Voltmeter

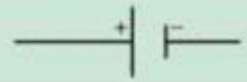
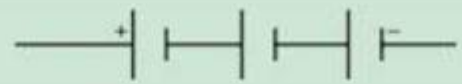
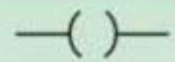
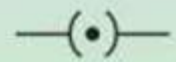
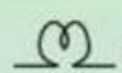
- A **voltmeter** is an instrument used for measuring electrical potential difference between two points in an electric circuit.

- Voltmeter has a high resistance so that it takes negligible current.



Ammeter

- An **ammeter** is a measuring instrument used to measure the electric current in a circuit. Electric currents are measured in amperes (A), hence the name.
  - An ammeter should have a very low resistance so that it may not change the value of current flowing in the circuit.

Sl. No.	Components	Symbols
1	An electric cell	
2	A battery or a combination of cells	
3	Plug key or switch (open)	
4	Plug key or switch (closed)	
5	A wire joint	
6	Wires crossing without joining	
7	Electric bulb	 or 
8	A resistor of resistance R	

Ohm's Law

- Ohm's Law explains the relationship between voltage (V or E), current (I) and resistance (R)
- According to Ohm's law : At constant temperature, the current flowing through a conductor is directly proportional to the potential difference across its end.

$$V \propto I$$

$$V=IR$$

Resistance

- An electron traveling through the wires and loads of the external circuit encounters resistance. **Resistance** is the hindrance to the flow of charge. For an electron, the journey from terminal to terminal is not a direct route. Rather, it is a zigzag path that results from countless collisions with fixed atoms within the conducting material. The electrons encounter resistance - a hindrance to their movement.
- The S.I. unit of resistance is ohm's (Ω).

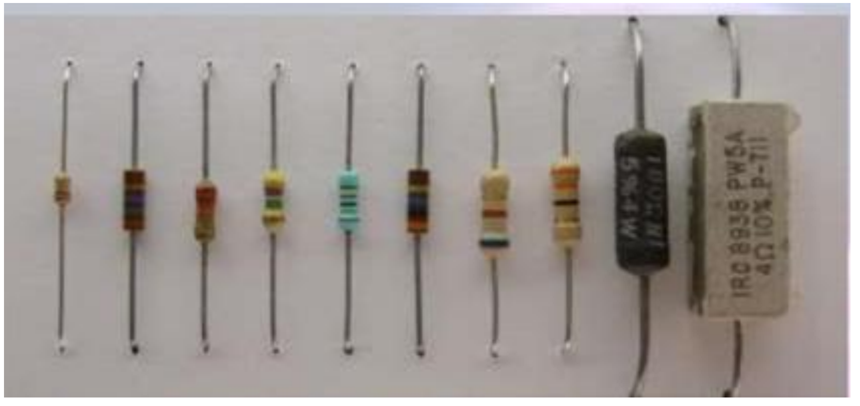
Factors affecting Resistance

i. Length of conductor.

ii. Area of cross section of the conductor (or thickness of the conductor).

iii. Nature of the material of the conductor, and

iv. Temperature of conductor.



- It has been found by experiments that :
- The resistance of a given conductor is directly proportional to its length.

$$R \propto l \text{ ……………..(1)}$$

- The resistance of a given conductor is inversely proportional to its area of cross section.

$$R \propto 1/A \text{ …………… (2)}$$

Combining (1) and (2), we get :

$$R \propto l/A$$

$$R = \frac{\rho L}{A}$$

- Where *p*(rho) is a constant known as resistivity of the material.
- The resistivity of a substance is numerically equal to the resistance of a rod of that substance which is 1 meter long and 1 square meter in area
- The S.I. unit of resistivity is ohm-meter (Ωm)

.

Combination of Resistors

- Resistors can be combined in two ways
  - In series
  - In parallel.

Resistors in Series

- When two (or more) resistors are connected end to end consecutively, they are said to be connected in series.
  - According to the law of combination of resistance in series: **The combined resistance of any number of resistances connected in series is equal to the sum of the individual resistances.**

$$R = R_1 + R_2 + R_3 + \ldots\ldots\ldots$$

I. When a number of resistors connected in series are joined to the terminal of a battery, then each resistance has a different potential difference across its ends (which depends on the value of resistance). But the total potential difference across all the ends of all the resistors in series is equal.

II. When a number of resistors are connected in series, then the same current flows through each resistance.

Resistances in Series

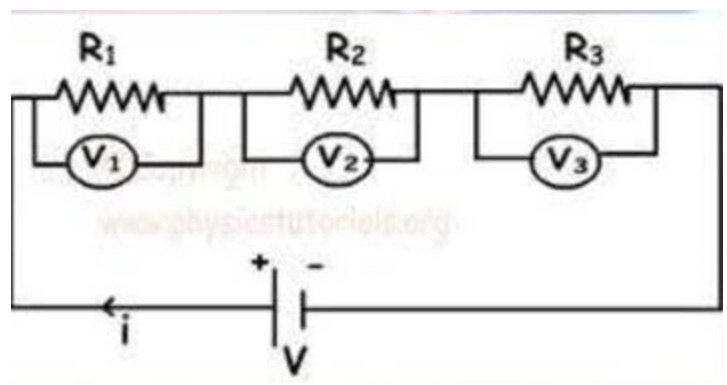
Applying Ohm's law to the whole circuit : $V = IR$. ………..(1)

Applying Ohm's law to the three resistors separately, we get:

$V_1 = I \times R_1$ …………………… (2)

$V_2 = I \times R_2$ …………………… (3)

$V_3 = I \times R_3$ …………………… (4)



Substituting (2), (3), (4) in (1)

$IR = IR_1 + IR_2 + IR_3$

OR, $IR = I(R_1 + R_2 + R_3)$

Or, $R = R_1 + R_2 + R_3$

Therefore we conclude that the sum total resistance in a series resistance connection is equal to the sum of all the resistances.

Resistors in Parallel

- When two (or more) resistors are connected between the same points, they are said to be connected in parallel.
  - According to the law of combination of resistance in parallel:

The reciprocal of the combined resistance of any number of resistances connected in parallel is equal to the sum of the reciprocals of the individual resistances.

$$1/R = 1/R_1 + 1/R_2 + 1/R_3 + \ldots\ldots\ldots$$

  - When a number of resistances are connected in parallel then their combined resistance is less than the smallest individual resistance.

- *When a number of resistance are connected in parallel, then the potential difference across each resistance is same which is equal to the voltage of battery applied.*
- *When a number of resistances connected in parallel are joined to the two terminals of a battery, then different amounts of current flow through each resistance (which depend on the value of resistance). But the current flowing through each parallel resistance, taken together, is equal to the current flowing in the circuit as a whole. Thus, when a number of resistance are connected in parallel, then the sum of current flowing through all the resistances is equal to the total current flowing in the circuit.*

Resistances in Parallel

- The figure shows three resistances R_1, R_2, R_3 connected in series. Now suppose currant across resistance R_1 is I_1, R_2 is I_2 and R_3 is I_3. Let total current in the circuit be I, then:

$$I = I_1 + I_2 + I_3 .$$

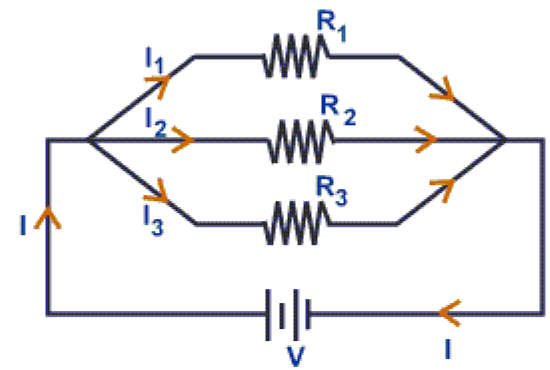
Applying Ohm's law to the whole circuit : I = V/R. ………..(1)

Applying Ohm's law to the three resistors separately, we get:

$I_1 = V / R_1$. …………………… (2)

$I_2 = V / R_2$. …………………… (3)

$I_3 = V / R_3$. …………………… (4)



Substituting (2), (3), (4) in (1)

$V/R = V/R_1 + V/R_2 + V/R_3$

OR, $V/R = I\,(1/R_1 + 1/R_2 + 1/R_3)$

Or, $1/R = 1/R_1 + 1/R_2 + 1/R_3$.

Therefore we conclude that the sum total resistance in a parallel resistance connection is equal to the sum of reciprocal of all the resistances.

Parallel and Series connection

Parallel connection

- If one electric appliance stops working due to some defect, then all other appliances keep working normally.
- In parallel circuits, each electric appliance has its own switch due to which it can be turned on or off independently.
- Each appliance gets same voltage as that of power source.
- Overall resistance of household circuit is reduced due to which the current from power supply is high.

Series connection

- If one electric appliance stop working due to some defect, then all other appliances stop working.
- All the electric appliances have only one switch due to which they cannot be turned on or off separately.
- In series circuit, the appliances do not get same voltage (220 V) as that of the power supply line.
- In series circuit the overall resistance of the circuit increases due to which the current from the power source is low.

Heating effect of electric current

- When electricity passes through a high resistance wire like a nichrome wire, the resistance wire becomes very hot and produces heat. This is called the heating effect of current.

Joule's law of heating

Let

An electric current I is flowing through a resistor having resistance equal to R.

The potential difference through the resistor is equal to V.

The charge Q flows through the circuit for the time t.

Thus, work done in moving of charge Q of potential difference V = VQ

Since, this charge Q flows through the circuit for time t,

$Therefore, Power\ input\ (P)\ to\ the\ circuit\ by\ power\ source = \frac{VQ}{t}$

$\Rightarrow P = V \times \frac{Q}{t} ------(i)$

$We\ know\ that, electric\ current\ (I) = \frac{Q}{t}$

$Thus, by\ substituting\ \frac{Q}{t} = I\ in\ equation\ (i) we\ get$

$P = VI --------(ii)$

Since the electric energy is supplied for time t, thus after multiplying both sides of equation (ii) by time t, we get

$P \times t = VI \times t = VIt ----------(iii)$

$Thus, for\ steady\ current\ I, the\ heat\ prouduced\ (H) in\ time\ t\ is\ equal\ to\ VIt$

$or, H = VIt --------------(iv)$

$According\ to\ Ohm's\ Law, we\ know\ that\ V = IR.$

$Therefore\ by\ subtituting\ V = IR\ in\ equation\ (iv) we\ get$

$H = IR \times It = I \times I \times Rt$

$\Rightarrow \mathbf{H = I^2Rt} ----------(v)$

- The heat produced in wire is directly proportional to

i. Square of current.

ii. Resistance of wire.

iii. Time for which current is passed.

Applications of heating effect of electric current

There are many practical uses of heating effect of current. Some of the most common are as follows.

- An incandescent light bulb glows when the filament is heated by heating effect of current, so hot that it glows white with thermal radiation (also called blackbody radiation).
- Electric stoves and other electric heaters usually work by heating effect of current.
- Soldering irons and cartridge heaters are very often heated by heating effect of current.
- Electric fuses rely on the fact that if enough current flows, enough heat will be generated to melt the fuse wire.


Thank You!

SEMICONDUCTOR PHYSICS

Semiconductors are the material, which have conductivity less than conductors and more than insulators.

For example:- Silicon and Germanium.

TYPES OF SEMICONDUCTOR

1. **Intrinsic semiconductors:-** These semiconductors are the purest and their conductivity is very low.

2. **Extrinsic semiconductors:-** To increase the conductivity some impurity is added to the pure semiconductor, so that the conductivity increase. This process is known as doping.

These are of two types:-

i) **N-type semiconductors:-** When pentavalent impurity like phosphorus antimony or bismuth is added to pure semiconductor, one extra electron is added for every doped atom, so that the number of electrons will become more and it is called N-type semiconductors.

ii) **P-type semiconductors:-** When trivalent impurity like boron, aluminium is added to the pure semiconductor, one hole becomes free for every doped atom, so that the number of holes become more and it is called P-type semiconductors.

PN-JUNCTION DIODE

When a P-type semiconductor is brought in contact with the N-type semiconductor, the resulting arrangement is called PN-Junction Diode.

In this, the electrons from N-type move to P-type and holes from P-type to N-type. The region in between P and N type is called depletion layer.

Barrier potential:-

Minority carriers in P-type and N-type semiconductors namely electrons and holes respectively try to move towards the regions where they are in excess and so their number on both sides of depletion layer increases which produces a potential difference between the two sides of depletion layer called potential barrier.

RECTIFIER

A rectifier is mainly a device which converts Alternating Current (AC) to Direct Current (DC)

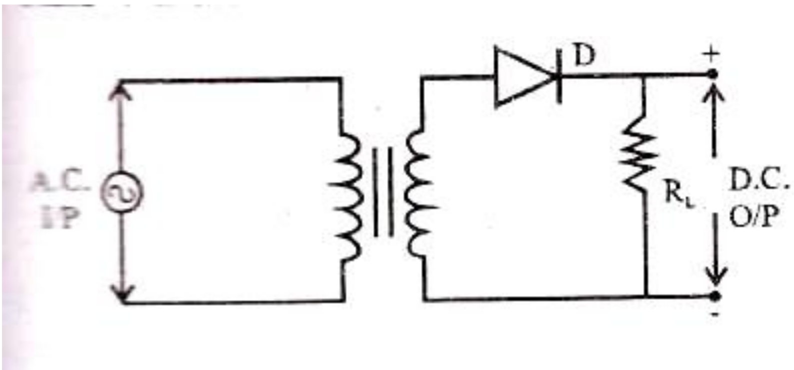
Two types of rectifier:-

i) Half wave rectifier.
ii) Full wave rectifier.

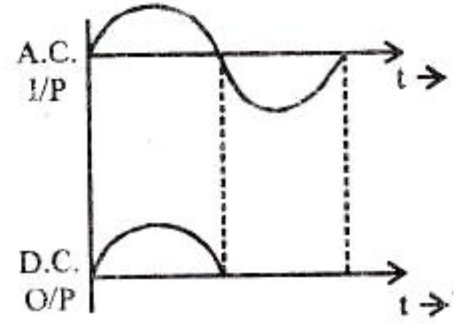
HALF WAVE RECTIFIER

The process of removing one-half the input signal to establish a DC Level is called Half Wave Rectification.

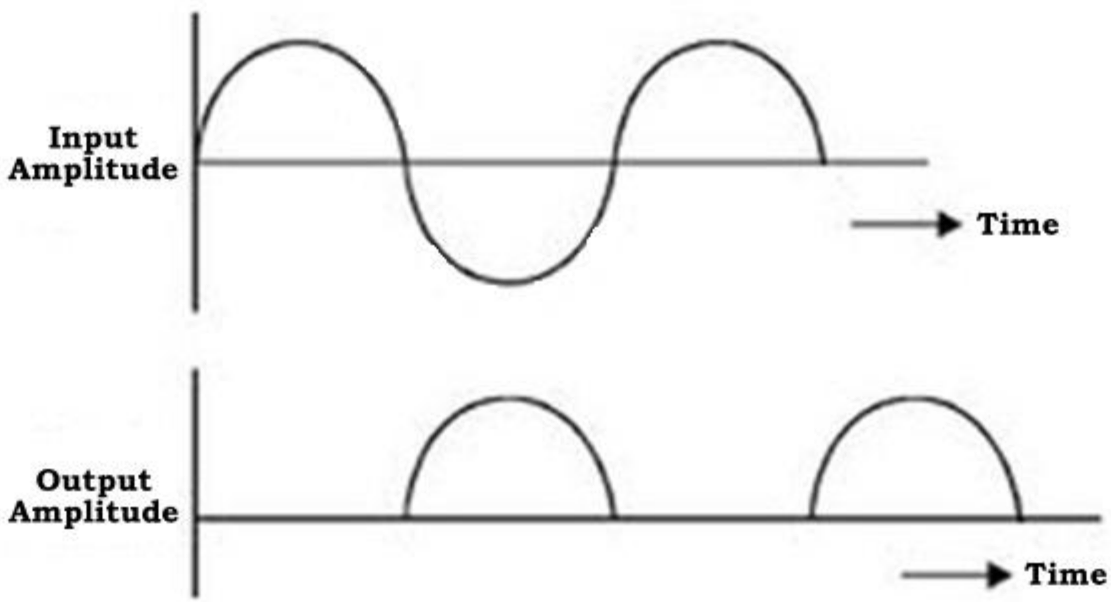
In Half Wave Rectifier only half of the wave i.e. positive half cycle appears at the output and negative half cycle is suppressed.



a) Half wave Rectifier



b) Wave forms



WORKING

The AC supply to be rectified is given through a transformer. The transformer is used to step-up or step-down. During positive half cycle of input AC voltage the terminal A is positive so that diode is forward bias and current appears across R_L.

During negative half cycle polarity changes and diode reverse bias and no current flows.

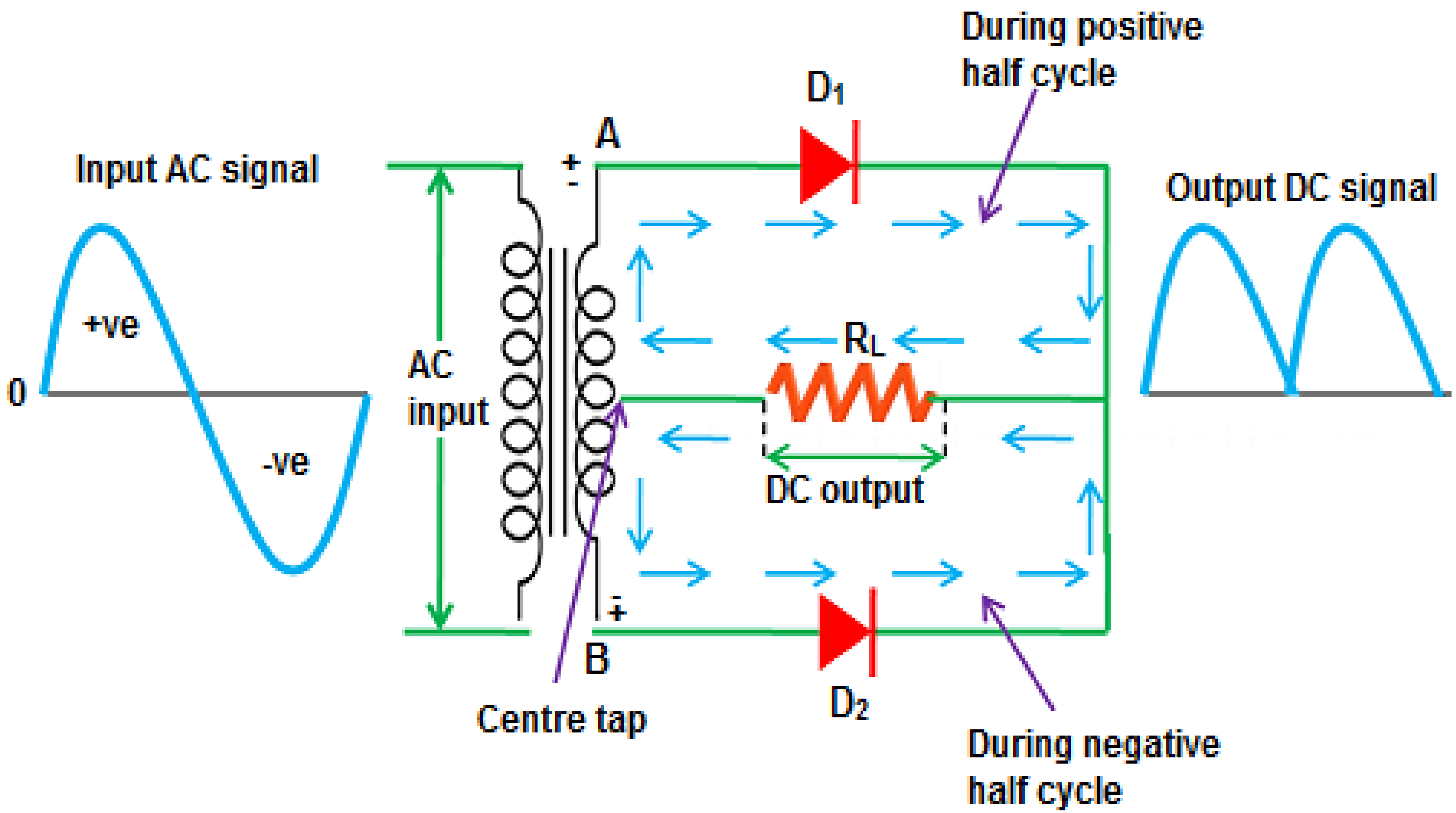
DISADVANTAGES

i) The output is low because a.c. supply delivers power for half cycle only.

ii) The output contains a lot of ripples.

FULL WAVE RECTIFIER

To overcome the limitation of half wave rectifier, full wave rectifier is used in which output appears for both the half cycle.



During positive half cycle
D1
A
Input AC signal
Output DC signal
+ve
0
-ve
AC input
RL
DC output
B
Centre tap
D2
During negative half cycle

WORKING

When AC is switched on, the ends A and B become +ve and –ve during +ve half cycle, so that diode D_1 being forward biased and current will appears across the R_L. During –ve half cycle B is +ve and A is –ve, so that diode D_2 being forward biased and current will appears through R_L. Hence, both the half cycles are utilized for the output.

ADVANTAGES

The output and efficiency is high, because AC supply delivers power during both the half cycles.

LASER

The term “LASER” is an acronym for “LIGHT AMPLIFICATION BY STIMULATED EMISSION OF RADIATION”. It is a device which is used for producing highly intense, strongly monochromatic, highly coherent and collimated beam of light.

CHARACTERISTICS OF LASER

- Monochromatic Light.
- Coherent Light.
- Directionality.
- Energy.
- Focusing.

LASER ACTION

1. Energy is applied to a medium raising electron to an unstable energy level.

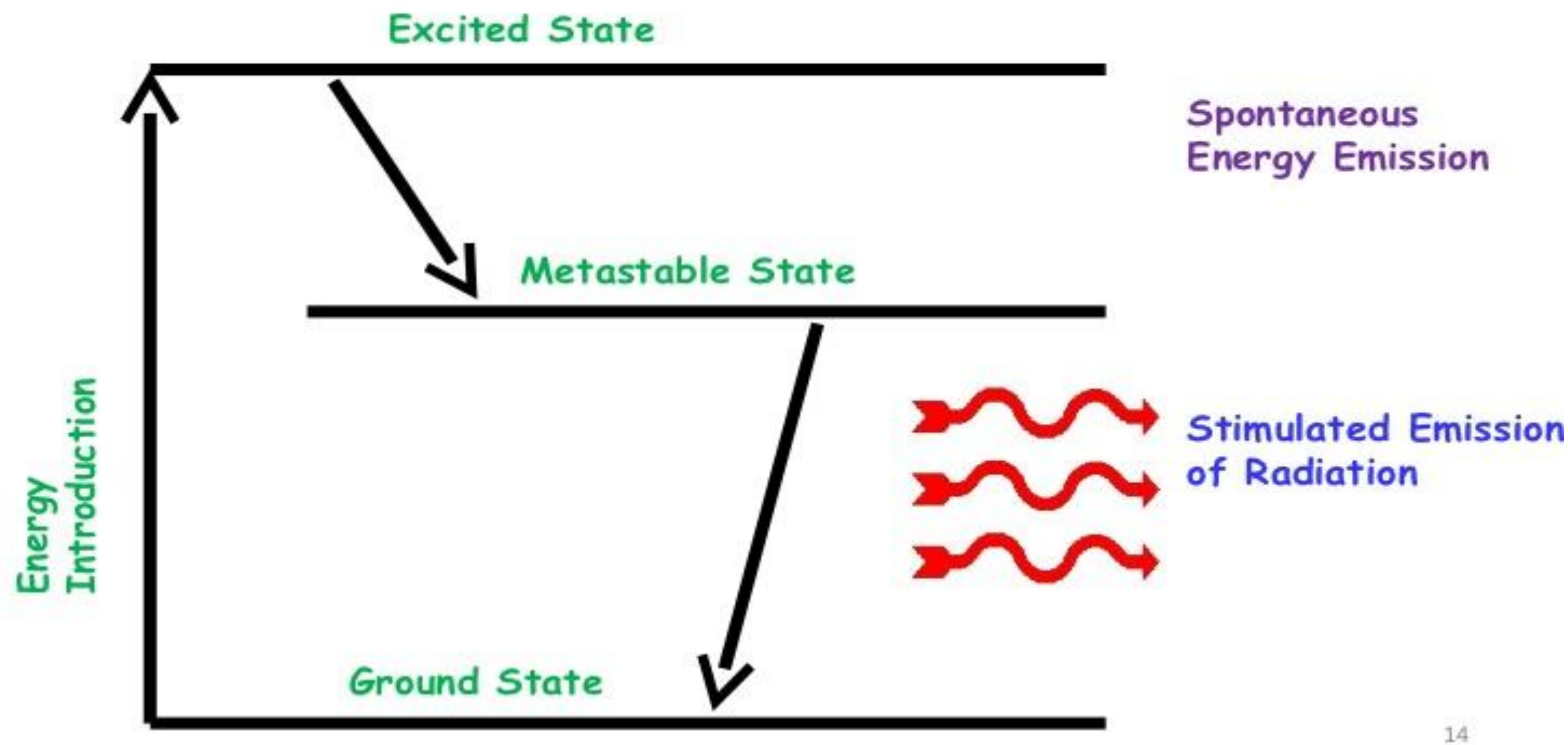
2. These atoms spontaneously decay to a relatively lower energy level, which is metastable state.

3. A population inversion is achieved when the majority of atoms have reached this metastable state.

4. Lasing action occurs when an electron spontaneously returns to its ground state and produces a photon.

5. If the energy of this photon is of appropriate wave length, it will stimulate the production of another photon of same wave length and laser action occurs.

Lasing Action Diagram



APPLICATIONS OF LASER

Engineering Applications:-

1. Drilling.
2. Cutting.
3. Welding.
4. Heat Treating.
5. Cladding.

Medical Applications:-

1. **Surgical laser:-** Removing Tumors, making incisions.
2. **Cosmetic treatments:-** Removal of birth mark, age spots, spider veins, hair, tattoos.
3. **Ophthalmology:-** Inner eye surgery in removing cataract, repairing retina, correct near sightedness.